CSCL 2005
The Next 10 Years!

Proceedings of the International Conference on Computer Supported Collaborative Learning 2005

May 30 - June 4, 2005 TAIPEI, TAIWAN

Edited by Timothy Koschmann, Daniel D. Suthers, Tak-Wai Chan

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Edited by

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Preface

This conference (and its associated proceedings) is auspicious in two regards—first, it marks the tenth anniversary of the first CSCL conference held at Indiana University in 1995 and, second, it represents the first CSCL conference to be held in the Asia/Pacific region. The latter is, of course, important because of the opportunity it affords for expanding both the CSCL community itself and the base of ideas upon which it operates. The former is even more important, however, because it provides an occasion for reflection on how the field has changed in the intervening decade and where it needs to move in the one to come.

The collection of papers comprising this volume is impressive! They range from theoretical proposals to meta-analytic reviews to methodologically diverse empirical pieces. They draw upon a variety of disciplines including communication studies, computer science, education, psychology, and sociology. Among the authors are many leaders of their respective fields, and as a group they represent all regions of the world in which relevant research is being conducted. In total, 252 papers were submitted for this conference, of which exactly 100 were accepted for presentation at the meeting and publication in this volume. Papers were accepted in two publication formats: full or short. Of the 166 full paper submissions, 31% were accepted in that category. Many papers received nominations for either the Best Paper award or the Best Student Paper award. Those papers receiving two or more nominations are marked with BPN (Best Paper Nomination) or BSPN (Best Student Paper Nomination) in the Table of Contents.

Two years of hard work went into planning this conference. Space does not allow us to individually credit all the people who contributed in one way or another to this elaborate undertaking. We would, however, like to extend our heartfelt appreciation to the members of the steering committee and the staff at our respective universities for their assistance, and especially to Ben Chang of National Central University, who contributed tremendously to all aspects of the planning of the conference and the compilation of this volume.

Also deserving of special commendation are the many colleagues who reviewed proposals for this conference. Our approach to paper selection was the most ambitious of all CSCL conferences convened to date. Recognizing the growing and international community we serve, an effort was made to treat the reviewing process as an opportunity for community building and collaboration. We solicited approximately 1200 reviews from researchers around the world, both those currently active in the CSCL community and those with special disciplinary expertise relevant to the submitted papers. Wherever consistent with reviewer expertise and availability, we assigned reviewers from the Americas, the Asia/Pacific region, and Europe to each and every paper. Reviewers were encouraged to read and discuss each other's commentaries, especially in cases where reviews were discrepant, and were given the opportunity to revise their own reviews. The program co-chairs wrote meta-reviews for every submission. The ultimate credit for the quality of the technical program, therefore, rests with those who contributed to this process. The fruits of their efforts can be seen in the pages of this volume, both in its selectivity and through the valuable feedback provided to the paper authors. We dedicate this collection to their diligence and commitment to the field.

Tak-Wai Chan
Timothy Koschmann
Daniel Suthers

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Action Context and Target Context Representations: A Case Study on Collaborative Design Learning

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Abstract. This paper focuses on the concept of representations produced in the context of collaborative design. More specifically, on the interplay between collaborative creation of sketches (design proposals), and argumentation and negotiation processes taking place in the design activity. The question raised in this paper is how sketches produced during a design session reflect and mediate dialogues and argumentation in the design activity and how the sketches feed into an envisioned use context or vice versa. The concepts of *action context*- and *target context representations* are introduced and used to illustrate shifts of focus during a design session. We have studied a group of students working on a design task in an interactive space for two weeks. The purpose of the study was to investigate how an environment meant to support collaborative work and learning support collaborative and creative learning of interaction design. The results indicate that students attending a course on interaction design did not pay enough attention to target representations. Furthermore the results suggest that "action context representations" to a large extent occupy student activities as a result of either complex technology or as a result of the students thrust to do something instrumental. We suggest that pedagogical programs for collaborative learning of design may relieve some of the mapping, or interplay, of design proposals and the target context representation.

Keywords: Design, Communication, Interactive Spaces, Learning, Representation

REPRESENTATIONS AS RESOURCES FOR ACTION

Collaborative design can be viewed as an activity driven by communicative practices and representations for mediating ideas. In domains such as design, and interaction design in particular, learning goals are often difficult (if not impossible) to define in a precise manner. In this sense, design, interaction design and learning of these domains is often ambiguous and evolving rather than pre-defined. The need to propose, discuss and evaluate different ideas, design proposals, etc. is therefore crucial to learning and practice of design. In professional design, negotiation is a crucial part of the design situation and the student has to appropriate such knowledge to be prepared for this. Designers must learn not only the skill to design visual design, and design that is in line with some general aesthetic principle but also to learn how to negotiate the relation or the interplay between some actual system design and design of use (Arvola & Larsson 2004). Especially, in the conceptual stages of design, negotiations between different designers (system architecture, database designers, interaction design) are important, but also when integrating designs it is important, particularly if the general design concept has not been agreed upon or not been dealt with thoroughly to negotiate and mend the design proposal. In this paper we pose the question of relations between physical sketches and conceptual design imperatives.

In the study of complex situations the concept of *representations for action* has been suggested (Weill-Fassina, 1993; Rabardel and Dubois, 1993). Representations for action refer to the representations that people have of the situation they are part of and focuses on people's actions, how people act in relation to what others' do and say with or without artefacts. The temporality of the situation is very much dependent upon the communicative acts that people do, for example one might refer to the immediate context or to future or historical situations. Design as an activity is often directed towards the future in that the designed system will be used in some situation apart from the one the designer is in – that is the designer representation for action is, or should be, oriented towards the future. To learn to design is as much of building and communicating a repertoire of motivations for the future use-context as it is to actually build something that fulfils more immediate construction. Interaction designers must have some understanding, or representation if you like, of the interactions that the users will do. Thus the problem a team of designers who design a common object face is on the one hand to coordinate a common representation of the future use situation, and on the other hand a smooth mapping of mediated representations for actions within the context of design activities. We call these contexts *target context* and *action context* respectively.

Sketching, drawing, thus representing design ideas and learning to represent ideas have been found to be crucial to the design process and also to development of design ability (Löwgren & Stolterman, 1998). This is what the general design research has focussed on and what we call action context representations, i.e. the use of supportive tools within the design environment and those skills a designer must have in order to make good design proposals in action (Gedenryd, 1998; Lawson, 1997; diSessa & Cobb, 2004). Generally, the arguments are focused on the solitaire designer with much creativity and talent, rather than collaborative efforts and accomplishments within designer teams. We will instead focus on communicative practices which designers use in order to convey ideas and negotiate design (see Sundholm, Artman, Ramberg, 2004; Sundholm, Ramberg, Artman, 2004 where we have discussed creativity in collaborative design). This means that we do not focus on some general mental mechanism, talent or other trait, but rather how team members communicate and negotiate different solutions to an envisioned use situation. We are in this paper especially interested in describing how design can be viewed upon as an oscillation between different forms of design contexts, and how different forms of representations support or undermine collaborative design activities. This motivates a focus on the interplay between collaborative creation of sketches (design proposals), argumentation and negotiation, and how sketches that are created mediate discussions and argumentation and feed into new ones, and to what degree characteristics of artefacts in the environment that are used in the process permit coming to discussions of the target use situation.

Engeström & Escalante (1996) presented a case where the designers fell in love with their design, the action context representations they created. The design became an idealistic vision, supported by suggestive design proposals and argumentation, which resulted in neglecting practicalities of use. A hypothesis is that inexperienced interaction designers may be immersed in *action context representations* resulting in that *target context representations* are not attended to or even ignored. Ideally, a design environment should support designers and design activities to focus on target context representations.

ILOUNGE – AN INTERACTIVE SPACE

At the Royal Institute of Technology in Kista, Sweden, there is an interactive space called the iLounge designed and built to support collaborative work and learning. The room has two large touch-sensitive displays known as Smart boards built into a wall. In front of this wall there is a table with a horizontally embedded touch sensitive plasma screen. This interactive table is large enough for 6 to 8 people to sit around. In one of the corners of the room a smaller table and three chairs are placed in front of a wall-mounted plasma display, enabling a part of the group to work separately. In short, iLounge supports collaboration through; *Large* screens that can show material that can be viewed and discussed by a whole group of people; The contents of the screens can be *shared* by the participants – documents can be edited by the participants; The screens are *interactive* – the participants can edit material on the shared screens through their own keyboards or directly using the touch screens; *Multiple screens:* several wall screens and a large horizontally embedded plasma screen (a table) are used instead of just one permitting the participants to work in more flexible ways, e.g., the participants can easily shift between working in groups or working individually on a subtask; *Multiple computers*: apart from the computers in the room, people can also bring their lap-tops and connect to a wireless LAN. This allows for flexibility (bringing documents and other work related information) and the possibility to work on a familiar platform. Also, more people can actively contribute to the ongoing work rather than having one person taking control of events. Figure 1 shows a plan of the room. The room has a wireless network and keyboards and mice in the room are also wireless, using Bluetooth technique.

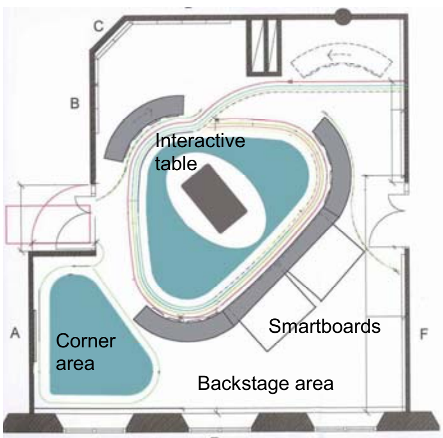

Figure 1. Plan of the room. The working areas are shadowed.

To facilitate and support work in the iLounge, services that help and support the user to move data between the devices present in the room have been developed. The services include Tipple[1] (allows users to open files on another computer), Multibrowse (allow to move web content on different displays) and PointRight [2](allow one pointing device on several computers). PointRight together with iClipboard makes it possible for the user to cut or copy text between computers in the space. The text is placed on a clipboard that is shared by the computers running the service.

Finally, the iLounge contains high quality audio and video equipment that for instance can be used when having videoconferences, or during user studies.

METHOD AND DATA COLLECTION

Five female and four male students in the ages of 21 to 45, divided in two groups, participated in the study. One group consisted of three men and one woman, and the other group of one man and four women. Some of the students in the groups knew each other from before. The students attended a course in design of interactive systems. The students' task was to design a digital, multimedia guide for an exhibition "4, 5 Billion Years - The History of Earth and Life" at the Swedish Museum of Natural History. The two groups were responsible for designing the multimedia guide describing "from Big bang to first life", and "pre-historical mammals". The target group was children about twelve years old. We followed the students during the conceptual design phase of their assignment. The conceptual design phase lasted two weeks and consisted of brainstorming, sketching of scenarios and the multimedia product, and information search. During this time the groups had four and five sessions, respectively, in the iLounge. Prior to this, they received an introduction to the environment and the specific services introduced in the section "iLounge" above.

Data were collected through observations, pre- and post-study questionnaires, and ended with semi structured group interviews. Both the work sessions and the interviews were video taped. The recordings consist of four angles to cover the whole workspace (see figure 2), and one channel for sound. Altogether the data material consists of 21, 5 hours of video data. As a tool for our analysis we have used interaction analysis (Jordan & Henderson, 1995), and more specifically, certain foci for analysis, namely spatial organization of activity, participation structures, artefacts and documents, turn-taking, and trouble and repair.

Figure 2. The view of the video recordings with four angles

THE INTERPLAY BETWEEN TARGET REPRESENTATIONS AND ACTION REPRESENTATIONS

As pointed out by Löwgren & Stolterman (1998), representing design ideas and learning to represent ideas through sketching and drawing have been found to be crucial to the design process and also to development of design ability. In the case accounted for here however, instead of using paper and pencil to sketch the participants worked on one of the two interactive screens for making sketches or for showing information found at the Internet to each other. While producing a sketch, one of the group members usually stood in front of the

[1] Tipple is developed by the FUSE group, Stockholm University/ Royal Institute of Technology, and can be downloaded at http://www.dsv.su.se/fuse/downloads.htm

[2] Multibrowse, Pointright and iClipboard are part of the iWork package and are developed by the Interactive Workspaces at Stanford University. The iWork services can be downloaded at http://iwork.stanford.edu/download.shtml.

screen, and the other participants were sitting around the table. The person in charge of drawing the sketches alternated. For instance, one participant could be using the touch functionality of one of the screens, another using the keyboard and mouse working on the same document, and a third using PointRight and iClipboard to insert a piece of text, and together they created a sketch.

Excerpt 1 illustrates that although the group had become acquainted with and used the interactive screens during the first session they still felt somewhat uncomfortable in using these during the second session.

Excerpt 1. Group 2, session 2. Using the interactive screens to sketch[3]

Time 0.12.55	Person	Transcript of interaction	Characteristic of action
1	#3	"We can also put some pictures here [in the Notebook]".	Sits down. Looks at the right interactive screen
2	#1	"You mean, when we draw the proposals we can do it with the interacti…"	Looks at #3 sitting next to #1.
3	#3	"Mmm, but we can draw now. We have written down some things about what we want. I don't know exactly what we are going to do now."	Looks at the right interactive screen
4	#1	"Mmm… We can do that."	Looks at #3.

An obvious drawback in using the interactive screens to sketch is that the interactive screens and the tools that support sketching and drawing makes very raw and clumsy sketches as compared to using paper and pencil. A positive outcome is that discussing around the interactive Smartboard is a collective act directed towards the team and put issues up front.

In the above excerpt, line 1, person #3, starts the episode with drawing attention to the use of pictures in order to start the design, which person #1 quickly follows with a question of how to use the interactive screens. Then in line 3 #3 is referring to a target representation of the use situation, but at the same time he is articulating his hesitation towards how clear this representation is for making a design proposal. Person #1:s response is focused on doing something by using the representational means i.e. the interactive screens. The two team members seem not to be synchronized in their endeavor to articulate visions and means. This kind of discussion is of course to be expected and in a sense constitutes a fruitful oscillation between the different forms of constraints to the design proposal. At the same time it may not be fruitful since the unfocussed discussion might stand for an anxiety of articulating either means or goals. However, the communication serves as a driving force for the team – each communicative initiative directs the team to consider new aspects of the design.

Interesting to note is also the transition between private and public, where drawing and sketching on a piece of paper followed by an attempt to translate or copy that onto the interactive screens allow the rest of the group members to see and react on the design ideas. In Excerpt 2, the continuation of the previous excerpt, we will see how going public and exposing ones sketches to the rest of the group produces dissatisfaction. This directs the communication and the actions towards the appearance of the *action context representations* they are creating.

Excerpt 2. Group 2. Continuation of excerpt 1.

Time 0.21.05	Person	Transcript of interaction	Characteristic of action
5	#3	"But if one draws something under here [shows with the pointer]. Or to make some more space.	Points with the pointer in the Notebook, on the right interactive screen.
6	#4	"Hm…"	Looks at the right interactive screen.
7	#3	"Some screens or something or… [refers to the design of the multimedia guide]"	Looks at the Notebook.
8	#4	"Yes. Is anybody good at this, to draw?"	Looks at #3.
9	#3	"I am very bad…"	Works with the Notebook.
10	#5	"So am I."	Looks at a Word document on the left interactive screen.
11	#4	"There are others…"	Looks at #3.
12	#1	"On where? There? [points to the right interactive screen] It is just to go there and draw with the hand."	Points at the right interactive screen.
13	#4	"Yeah, right! If… Is there anybody with some talent of drawing?"	Looks at #3.
14	#5	"We don't care about what the animals look.like"	Looks first at #3, then at the left interactive screen. Talks simultaneously to #1, line 12.
15	#5	"What are we supposed to draw?"	Looks at #2 and #3. Talks simultaneously to #3, line 13.

[3] The transcriptions below are divided with resemblance to the work of Pomerantz & Fehr (1997). But in our case "Characteristic of action" describes the actor's action, not the abstraction of the utterances.

16	#2	"Draw pictures of a screen with all the animals, maybe. It is just to make some dots."	Looks at #5.
17	#4	"Someone with some talent of drawing?"	Talks at the same time as #2, line 16. Talks to #1.

Here the interactive screens seem to be more inhibiting, than supporting coming to creative expressions. In line 14 person #5 tries to redirect the discussion away from the appearance of the design proposal that they are to create, but the team is stuck on the appearance and holds on to the discussion. We interpret this as person #5 is trying to include the issue that the appearance is mainly of interest when they have an idea of the use of the system. That is, person #5 tries to direct the issue of target context- rather than the action context representation. In line 16 person #2 seems to adhere to this shift in focus in pointing out that they simply have to "make some dots". Still, as the target context representation is not clearly articulated and shared the issue is dragged back to an issue of the here and now of making design sketches, where the focus is shifted again towards a more instrumental action context perspective. Although it seems that no one is willing to take on this instrumental perspective and actually do something. The problem was resolved by ripping pictures from the Internet and by using simple representations such as squares and circles, to signify animals. This was done using two interactive screens in parallel, one for using the Internet and one for using the drawing program. This is interesting since it illustrates the interdependence of two seemingly independent processes, and the relation of how the workspace layout is supporting creative solutions and creative use of representations in collaborative activities. Internet becomes an important source for them not to get stuck in the design process and action context representations. And also, the digital representations give the users the chance to re-negotiate and re-represent the design proposals. This discussion is facilitated by an easy access to the Internet, digital representations of animals as well as a shared surface for projection. This creative use of the artifacts gives an opportunity for the team members to re-focus on the use of the multimedia guide. It is a good example of the oscillation between action context discussions and target context discussions as well as of how technology can and should support these oscillations. More experienced designers often have learned different repertoires of design solutions to test and choose among that can help accomplish smooth oscillation, while inexperienced designers seem to need transparent and ready-to-hand support to be able to do this. However, as Lawson (1997) has shown, such design repertoires are very fragile and may easily break down when facing new use situations, which require new design solutions. Therefore we think that design studios should be designed with both action context- and target context representations in mind.

RE-INTERPRETING AN IDEA COLLABORATIVELY

The interactive screens were mainly used in two different ways. Mostly to present rudimentary sketches, often visual, to other team members as illustrated in figure 3. Individual sketches on paper sometimes preceded this. The other way to use the screens was to present web pages from the Internet, in order to discuss the information that was found, the design or other issues coupled to the project. In both cases the goal was to make information available to others in order to discuss (which makes it open for re-interpretation or disputing of the idea). In this way the team gets the "raw" information, rather than some pre-processed summary prepared by another team member.

Figure 3. A group discussion regarding design sketches

Excerpt 3 shows how the interactive screen is used to present an idea. The excerpt is taken from an early part of session 3, where the group still has not decided or agreed on the concept of the multimedia guide. Before the excerpt below begins the members of the group have discussed what children would like to know, and how deeply they should go in to particular details. While other group members try to solve some practical issues, #1 stands up, and starts to make a sketch of a proposal of a game on the left screen. The theme is a competition, “like a boxing game”, between animals.

Excerpt 3. Group 2, session 3. Presentation of ideas

Time 0.23.07	Person	Transcript of interaction	Characteristic of action
1	#2	“As one of the games, or…?	Sits down. Looks at #1.
2	#1	“Yes, but you can.., like this [pointing]… eh, I mean to eat or to be eaten, but you can choose, so you in one way or another, or maybe not like this. But you present the information about them, and then you can… or even if one might go here. But maybe also like this. “	Stands in front of the left interactive screen. First looks and points at the sketch, then looks at the group around the table, and finally points at the sketch again.
3	#1	“You might go like this in the forest somewhere. Here you have…”	Opens a new page in the Notebook and starts to visualize how #1 thinks by drawing with the finger.
4	#3	“But if you think we are going to do this in a real way, then we need to know what they sound like, and how they use their body, and knock, and…”	Sits down. Looks at #1 and #5. #3 sits on the opposite side around the table.
5	#1	[Mumbles something inaudible]	Sketches in the Notebook. Nobody pays attention.
6	#5	“It is built upon research [inaudible]...”	Sits down. Looks at #3
7	#1	“Then you can have different animals.”	Looks at the interactive screen, and start to draw with the finger in the Notebook. Nobody listens.
8	#3	“Watch Jurassic Park [the movie].”	Looks at #5.
9	#1	[Mumbles something about “a cave”]	Sketches first, then turns around and looks at the group.
10	#5	“Mm…”	Looks at #3

As we can see the idea is forming as it is successively formulated and represented. The team members are partly open to the idea, partly developing the idea but also tend to take the idea to a practical level of implementing it. This is one of the few instances where we have found the team formulating and pursuing ideas about the target context, that is, where the discussion in the group is more about the use of the multimedia guide than of the technology and the representations surrounding them. It seems as if having come to the solution of ripping pictures from the Internet relieves the group from having to focus on graphical details but can concentrate on the use of the guide. This gives witness to the group having found a meaningful use of the interactive screens and their functionality resulting in a stronger focus on target context representations. Learners of interaction design need support that facilitates and highlights the important relation between immediate actions carried out in the environment and a vision of actions and use in the target environment. Another way to say this is that learners need a support that helps them to shift between action- and target context representations, respectively.

DISCUSSION

If tools are not appropriated both to individual and team needs these tools will be a nuisance rather than a support. The nuisance steals attention, concentration and energy from the individual and in turn from the team. The tools become present-at-hand rather than ready-at-hand. This may sound like a renaissance cognitive idea of a given mental capacity, but our argument is rather that the communication among the team members is directed away from target context representations to action context representations. We certainly see that students of Human-Computer Interaction in general and interaction design in particular, must have some training in attending to and creating target context representations, be visionary if you like, in order to proceed with becoming skilled designers. This repertoire should both include a repertoire of using different tools, but also an empathetic repertoire of high-lighting use situations. The latter is unfortunately often forgotten, ignored or plainly not seen as an important repertoire as it can be explored at hand or after the fact. Our understanding and belief is the opposite.

One known problem with supportive representational environments is that each and every representation on their own may be supportive but when something goes wrong, or when the different representations are not mapped, much of the users work is to match the representations by handling the mismatch manually (Garbis & Artman, 2004). In this study we have found that the students oscillate between action and target context representations but also that an unclear target context representation does not guide the process resulting in that mapping action context representations take over the design process. Problems with action context representations may further hinder to articulate such use contexts. This is very problematic if one considers interaction design to be the design of use, rather than product design. One crucial problem appears to be how to share and communicate ones idea of the target context as well as to keep it alive while attempting to formulate and represent the idea in the action context. In this study we have observed students performing a task in collaboration but without any larger chunks, or vivid discussions about the context of the future use of the artefact being designed. In spite of this, students managed to come to creative solutions in handling artefacts in the action context subsequently resulting in the students being able to focus more on target context representations. At the moment we are designing pedagogical programs that structure the students work. The programme includes the division of labour into a design- and critique team. These teams work in parallel and meet on a continuous basis to discuss the design proposals from any angle. Our intention is to force the design learners to represent and motivate their design proposals to an outsider who is getting more and more involved in the design work. Furthermore, we are experimenting with design patterns in terms of user interface and task flows. One important intention with presenting design patterns, apart from providing students with concepts to practice on how to use, elaborate, etc., is to motivate the students to make conscious choices or combinations of alternatives as well as to relieve the students from only focussing on the action context representations and raise their perspective to the use situation i.e. the target representations. Learning the practice of interaction design includes much more than only making an appropriated design. It also involves practicing to make vivid presentations of the future use of the interactive system, thus training in attending to and creating target context representations. It is the use that should direct the design rather than design directing use, or is it not?

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Coercing Knowledge Construction in Collaborative Learning Environments

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Abstract. Multidisciplinary teams are often employed to solve complex problems, but research has shown that using such teams does not guarantee arriving at good solutions. Good team-solutions require team members possessing a good degree of common ground. In this contribution an ICT-tool based upon making individual perspectives explicit to other team members is studied. Two versions of the tool that differed in the extent to which users were coerced to adhere to embedded support principles were used, in both a laboratory and a secondary professional education setting. Coercion, as expected, increased negotiation of common ground in both settings. However, results were contradictory with regard the amount of common ground achieved. Overall, it can be concluded that NTool and its underlying framework affect negotiation of common ground, and that adding some coercion increases this effect. However, one should be careful with the specific task and audience before implementing NTool.

Keywords: Negotiation of meaning, common ground, ICT-tools, knowledge construction, coercion

INTRODUCTION

Professional organisations expect multidisciplinary teams to to achieve improved problem solving. Expectations are especially high in the case of solving complex problems, because multidisciplinary teams can employ multiple problem perspectives. Indeed, research has shown that engaging multiple perspectives may lead to richer solutions to complex problems (Lomi, Larsen, & Ginsberg, 1997), and that neglecting relevant perspectives can lead to solving the wrong problem, and in some cases even aggravate the problem (Hasan & Gould, 2001; Vennix, 1996). Research has also shown that individual team members have to engage each other's thinking in order for these expectations to hold (Barron, 2003). In other words, team members need to achieve a common cognitive frame of reference, or common ground (Bromme, 2000; Clark & Brennan, 1991) in order to reap the benefits of multiple problem perspectives. This contribution deals with the facilitation of grounding processes with an ICT-tool called NTool.

NTool is an online communication tool with embedded support of grounding processes. Like other ICT-tools, NTool uses specific communication rules (a formalism) and constraints (coercion) to attain this facilitation. These formalisms are tailored to facilitate specific aspects complex problem solving and coerce[1] (Dillenbourg, 2002) people to follow the formalism's rules. However, whereas other ICT-tools that aimed at facilitation of problem solving focussed mainly on structuring the problem or the argumentation (e.g., Buckingham Shum, MacLean, Bellotti, & Hammond, 1997; Eden & Ackermann, 2001; Van Bruggen, 2003),

[1] Some dictionary definitions (Webster's student Dictionary, 1996) of coercion hold that to coerce involves 'to constrain or force to do something'. We wish to stress that this contribution uses it in the sense of constraint, not force.

NTool is the first to address the grounding process at a more basic level. It does so by making users explicate their private understanding of other's contributions.

Researchers in the past have chosen to implement ICT-tools that use formalisms or constraints to structure conversation and discourse among collaborators with the aim of guiding the exchange of knowledge and information. Such ICT-tools are being used in fields and topics as diverse as design activities (Buckingham Shum et al., 1997), scientific reasoning (Suthers, 2001), and argumentation (Van Bruggen, 2003). Such tools have attained good results on cognitive aspects of group learning by focusing on task aspects. However, they have not explicitly addressed the problem of *common ground*.

In this contribution we report on two experimental studies in which two versions of NTool with different levels of coercion were tested. Study I was a laboratory experiment with university students in their senior year, while Study II took place in a practical educational setting with second year students of secondary vocational education. In Study II the effects of NTool over time were also studied. The goal of this contribution is threefold, namely to report on the effects of NTool on negotiation of common ground, to verify the laboratory findings in an educational setting, and to explore differences between the laboratory and practical educational settings.

A FRAMEWORK

Barron (2003) showed that team performance is related to team interaction, noting that willingness to construct shared problem spaces is essential for engaging multiple perspectives. In her study (2003), members of high performing teams engaged each other's thinking, while members of low performing teams typically ignored each other's proposals. Performance depended on the negotiation of a shared problem space as basis for construction of complex problem solutions. Teams in which the members critically explored each other's thinking and explicitly accepted, agreed, and subsequently documented contributions to the discussion, ultimately generated better problem solutions. According to Johnson and Johnson (1994), synthesis of multiple perspectives may result in better decisions and solutions to complex problems. Bromme (2000) argues that a team needs common ground - a shared cognitive frame of reference - before it can attempt to synthesise perspectives. In other word, members of multidisciplinary teams need some kind of commonality between their different perspectives in order to benefit from them.

In our framework, we address *knowledge construction* to reflect on how individual knowledge becomes part of a solution to a complex problem, and *group processes* to reflect on the team processes that take knowledge from being in the 'mind' of one learner to becoming a team's constructed knowledge. It is inspired by research and theory on social learning (e.g., Salomon & Perkins, 1998; Sullivan Palincsar, 1998), knowledge sharing (e.g., Boland & Tenkasi, 1995; Walsh, 1995), and grounding (e.g., Baker, Hansen, Joiner, & Traum, 1999; Bromme, 2000; Clark & Brennan, 1991). The route from unshared individual knowledge to team knowledge goes through three intermediate forms (external knowledge, shared knowledge, common ground) via four processes (externalisation, internalisation, negotiation and integration) (see Figure 1).

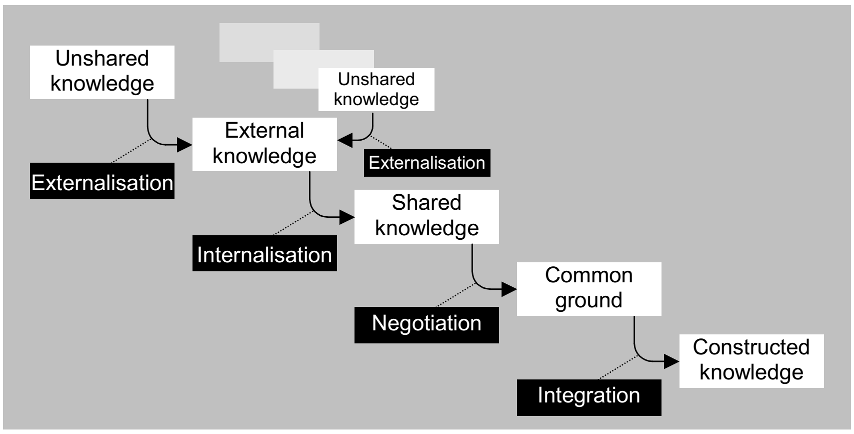

Figure 1. From unshared knowledge to constructed knowledge

Private knowledge is externalised when team members make their, as yet, unshared knowledge explicit or tangible to others (Leontjev, 1981), for example by contributing to a conversation. Once a team member has made such a contribution, the others can try to internalise it. While constructing their own individual understanding, the other tem members can consider knowledge of certain aspects such as the contributor's background, the current situation, and views held to better "understand" the contribution. Also, their own beliefs and assumptions play a role while trying to understand a contribution. A contribution is thus understood against the presumed perspective of the other, as well as against one's own perspective (Bromme, 2000). Having shared a contribution with a team does not mean that the team members all have arrived at the same understanding. Representational differences can result from interpreting a contribution in one's own perspective only (e.g., a graphical designer has a different understanding of the term "elegance" than a computer programmer) or from minimising or rejecting its validity or plausibility due to differences in conviction or opinion.

A shared contribution is the starting point for negotiation of common ground – the shared cognitive frame of reference (Bromme, 2000). It is through the process of internalising others' contributions, and subsequently providing feedback based on one's own perspective by word or action, that common ground can be negotiated (Alpay, Giboin, & Dieng, 1998; Baker et al., 1999). Common ground is never absolute or complete, but is continually accumulated and updated (Clark & Brennan, 1991).

Negotiation of common ground is conceived of as a dual concept in our framework. The first concept is negotiation of meaning which leads to an agreement regarding meaning and understanding of a contribution. This entails making private understanding of some *contribution* public to others, *verifying* whether and to what extent their own understanding of the contribution is different from what others intended, receiving feedback on this (*clarification*), re-verifying, and so on, until "the contributor and the partners mutually believe that the partners have understood what the contributor meant to a criterion sufficient for the current purpose" (Clark & Schaefer, 1989, p. 262, the grounding criterion). Negotiation of position, the second concept, concerns people making public to others their private *opinion* about a contribution, *checking* whether one's position is clear to others, and vice versa. Note that neither of these concepts implies the more common, generic use of the term negotiation, namely to discuss with an opposing or adversarial party until consensus or compromise is reached.

Starting from common ground, new knowledge can be built by adding new relations and concepts to common ground, via *integration*. Knowledge construction is based on the common ground the team has built, and will broaden and deepen the common ground because the common constructed knowledge becomes part of the common ground. With regard to problem solving, constructed knowledge represents the solution(s).

A FORMALISM TO SUPPORT NEGOTIATION

The steps from unshared to constructed knowledge in the above framework serve as a basis for a *formalism* for the support of negotiation. The formalism consists of *primitives* of negotiation, and *rules* that prescribe the use of these primitives. Primitives are basic building blocks that model a specific type of dialogue (Dillenbourg, 2002). These primitives are coupled to a set of rules to mimic the negotiation process as explicitly as possible, which results in a formalism for negotiation. Note that this formalism models an ideal negotiation process; in regular communication, the status of people's statements in terms of negotiation primitives often remains implicit. The formalism must enable distinguishing between original contributions, clarifications, verifications, et cetera, making the steps explicit. By doing so, individual differences in understanding and opinion should more easily surface.

First, negotiation starts with a *contribution* (Primitive 1) such as a hypothesis or a position, which is assumed not to be part of a team's common ground (Rule 1). To detect differences between individual representations, team members must *verify* (Primitive 2) their understanding of the contribution (Rule 2) because people articulate and understand a contribution against their own background knowledge (Fischer, Nakakoji, & Ostwald, 1995). Third, a contribution needs to be *elucidated* (*clarification*, Primitive 3), using the ideas upon which it was based. For example, the educational background or the political orientation of the contributor may shed light on the meaning of a contribution. Clarification need not always be made by the original contributor, but may also be performed by another team member who feels knowledgeable. Rule 3 is that all verifications require a clarification. Together, Rules 2 and 3 can be iterated until common understanding of the contribution is reached. Note here that a correct clarification of a contribution of one team member can be seen as a successful verification by another.

The fourth primitive is *acceptance/rejection* of a contribution, whether one can judge a contribution as true (acceptance), based on the explanation given, or untrue, or unintelligible (rejection). For example, the statement 1 + 1 = 10, is true only if we understand (through Rules 1 and 2) that the contributor is using the binary system. A contribution should be accepted as part of the common ground if it is true, or after it has been modified so that it has become true. Rule 4 is that every contribution needs to be accepted or rejected by the team members. Finally, Rule 5 is that people must explicitly state their own position (*position*, Primitive 5) on the contribution. In the case of irresolvable disagreement about previously accepted statements, Rule 5 may result in multiple scenarios, each based on another position (i.e., agree to disagree). This means that one may accept a certain contribution, but disagree all the same, for example when neither person can prove the other wrong. In such cases, people can agree to disagree, and alternate representations that are equally legitimate can ensue. Table 1 summarises these rules.

Table 1. Rules for a formalism for the facilitation of negotiation

1.	Every new issue is termed a *contribution*
2.	Contributions require a *verification* by the other team members
3.	Each verification is responded to with *clarification* by the original contributor
4.	When all verifications are clarified, and no new verifications are performed, all team members state whether they *accept* or *reject* the statement
5.	All team members state their *position* about accepted statements

The Negotiation Tool

The formalism for supporting negotiation was implemented in an ICT-tool called the NegotiationTool (NTool). NTool is based on a newsgroup reader for asynchronous, distributed, text-based discussions. To optimise NTool for negotiation of multiple representations, the formalism was implemented to structure the negotiation process in two ways with different levels of coercion (cf. Dillenbourg, 2002).

Coercion, a form of scripting, is defined as the degree of freedom participants have in following a formalism. Coercion and formalism together constitute a collaboration script. The higher the coerciveness of a script, the more the participants are required to adhere to the formalism. Scripting requires "subjects on most or all occasions to make a particular type of speech act in a specific context." (Baker & Lund, 1997, p. 176). For Dillenbourg (2002) a "script is a set of instructions regarding to how the group members should interact, how they should collaborate and how they should solve the problem." (p. 64). This means that a script can be aimed at either the interaction and collaboration level, for example by offering sentence openers or prescribing communicative acts (e.g., Baker & Lund, 1997; Barros & Verdejo, 1999; Soller, 2002) and/or the problem solving process, for example in problem-based learning. In such cases, scripting results in the use of distinct phases for discussion, with distinct purposes with regard to problem solving (Barrows & Tamblyn, 1980; Dillenbourg, 2002; O'Donnell & Dansereau, 1992).

A script that uses very little coercion leaves participants many degrees of freedom such that usage of the formalism attains a high degree of idiosyncrasy. A script with a high level of coercion constrains the number of options participants have, thus guiding them along the lines of the formalism. In the study reported here, two different ICT-implementations of the formalism were implemented (see Methods). One implementation had very little coercion and was called the *Idiosyncratic* version. This situation resembles giving a person a set of lines and symbols to be used in constructing a diagram, but leaving it up to her/him to decide which symbols and lines are used for what purpose. The other implementation used scripts aimed at interaction and collaboration (high coercion) and was called *Stringent*. In each implementation, coercion was aimed at the verification and clarification primitives, that is, the extent to which people were required to verify and clarify contributions in specific circumstances.

NTool was expected to increase negotiation of both meaning and position because it forced team members to make their private understandings and opinions public, making differences in understanding and opinion visible or salient (Bromme, 2000). We hypothesised that (1) the higher the level of coercion, the more negotiation would occur. We Likewise, we hypothesised that (2) common ground would be highest in the Stringent version and lowest in the Idiosyncratic version. Both hypotheses presume that more coercion will make participants follow more closely an ideal model of negotiation, as laid down in the formalism.

METHOD

Participants

Participants in Study I were senior students at Maastricht University from the departments of Cultural Sciences, Economics and Business Administration, and Psychology. Participants in Study II were second year secondary vocational education students from three different programmes, High-tech Metal-Electricity, Infrastructure, and Architecture. In both studies, participants were assigned to three-person multidisciplinary teams, which resulted in 12 teams in Study I, and 22 teams in Study II.

Task

In Study I participants were required to solve a "school drop-out" case (Kirschner, Van Bruggen, & Duffy, 2003). They received the task description: "You have been asked by the government to advise the Minister of Education how to solve the high school drop-out problem. At the end of the session you are expected to come up with a viable solution that can be implemented as government policy."

In Study II participants were assigned the task of making a functional design of floating housing as a remedy for sea-level rise. The task was designed in collaboration with teachers to ensure that the difficulty level was appropriate for the participants, and that the task was interesting to the different programmes. The task was split into two parts. In the first part ("Floating Houses") the participants designed a floating house. In the second part ("Amersfoort-by-the-Sea") additional information was given to keep the participants busy. Different though these tasks may seem, they both are complex problems (see Conklin & Weil, 1997), requiring multidisciplinary effort to solve them. In both cases the tasks were tailored to the various disciplines in the teams.

Formalism

Each team was supplied with one version of NTool. Each version was used by the same number of teams.

Idiosyncratic version. This version used only the primitives. On-screen information was presented on every contribution, and whether it needed verification or a decision (agreeing or disagreeing). Furthermore, participants were informed when they had not verified all contributions, and when they had not decided on all contributions.

Stringent version. This version used the same primitives, but allowed negotiation of only one contribution at a time. Furthermore, participants were not allowed to compose reject-, agree-, and disagree-messages before the contribution had been verified. Participants were informed, via prompts, as to whether they had to verify or decide on a contribution.

Procedure

Both experiments started with a practice phase. Study I had one experimental phase; Study II had two. The general procedure for these phases was the same for both studies, differences in timing are presented in Table 2.

Practice phase. Participants received a tutorial on the ICT-environment addressing the basics of NTool, and the formalism rules and how they constrained communication. To ensure that participants were proficient with NTool they received a practice case (about a problem of road traffic safety) to enable them to gain experience with NTool.

Experimental phase. After a 15-minute break, participants started working on the experimental cases. To promote the construction of an individual problem representation, as well as to allow the researchers to determine what this representation was, participants first had to carry out the task individually (pre-test). Participants could take notes while working individually. Next, they solved the problem collaboratively, and after that individually gave their solution (post-test). All resulting individual problem representations and solutions, as well as the group discussion were recorded. In their post-test, participants were also asked to state the points on which they felt that they had differences in opinion with their team members, to account for agreeing to disagree.

Study II had two experimental phases (a morning session and an afternoon session), with a 75-minute lunch-break between the sessions.

Table 2. Timing differences between Study I and Study II

	Study I	Study II
Practice phase	65 min	75 min
Tutorial	20 min	15 min
Practice	45 min	60 min
Experimental phase	130 min	90 min
Pre-test	20 min	15 min
Collaboration task	90 min	60 min
Post-test	20 min	15 min

Variables and Analysis

Negotiation was measured by analysis of the collaboration. Common ground was measured by comparing individual representations before and after collaboration.

A coding scheme for coding function and content of messages during collaboration was developed (cf., e.g., Avouris, Dimitracopoulou, & Komis, 2003; Fischer, Bruhn, Gräsel, & Mandl, 2002; Mulder, Swaak, & Kessels, 2002; Thomas, Bull, & Roger, 1982). All messages were coded with regard to:

- Cognitive content - directly related to solving the problem.
- Regulative content - related to monitoring the problem solving process, regulating the collaboration process, which also entailed tool use.
- Other content - not in any other category or non-codeable.

Messages with cognitive content were specifically coded for function. The following subcategories were used:

- Contribution: A new topic of conversation that has not been discussed before is introduced.
- Verification: Information directly or indirectly requested about the intended meaning of a contribution.
- Clarification: A reaction to a verification or a perceived lack of understanding, where the intended meaning of a contribution or elaboration is elucidated.
- Acceptance: A reaction to a contribution in which the contribution is judged intelligible and/or correct.
- Rejection: A reaction to a contribution in which the contribution is judged unintelligible and/or incorrect.
- Agreement: A reaction to a contribution in which the sender voices his/her agreement with the contribution.
- Disagreement: A reaction to a contribution in which the sender voices his/her disagreement with the contribution.

In many cases, messages did not fit any of the above subcategories, for example if people built on each other's communications, without explicitly negotiating meaning of, or position on a contribution. Such messages were coded *Elaboration*: A contribution is elaborated upon by adding information or summarising. *Verification and clarification*, in contrast to elaboration, were considered indicative of explicit negotiation activities. The total number of contributions discussed was used as an indicator for the range of topics discussed.

Research-assistants were trained to use the coding scheme using data from the practice phase. Each assistant coded the data from one study. Comparing one randomly selected experimental session coded by the first author and a research-assistant resulted in substantial (Landis & Koch, 1977) inter-rater reliability (Cohen's kappa) for both studies, .70 (SE = .034) in Study I, and .73 (SE = .024) in Study II.

Common ground. Common ground was operationalised as the extent to which the content of individual representations was present in individual representations. The contributions identified in the coding procedure were used to characterise the content of the individual representations.

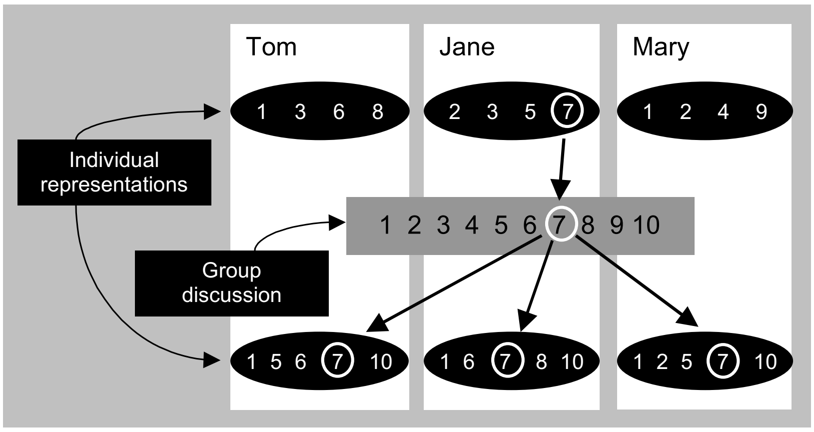

Figure 2. Analysis of common ground; numbers indicate contributions

Each contribution was first numbered and summarised. The next step involved characterising the content of all individual representations, both initial (pre-test) and subsequent to collaboration (post-test), and the group representation. The summaries were used to identify the content within individual the representations. For every individual representation the topics that were and were not represented were assessed. For example, in Figure 2 episode number 7 is present in Jane's initial individual representation, in the group discussion, and in all post-tests. By repeating this procedure for each of the contributions in the discussion, the origin of each topic, whether it was present in the group representation, and whether participants used it in their post-tests was determined. Using these data we computed, for each group, the mean number of pre-tests and post-tests that a contribution would end up in. This mean number of post-tests per contribution was used as a measure of common ground.

Statistical analyses

Statistical testing was done using various ANOVA techniques. Negotiation was analysed using ANOVA, and common ground using ANCOVA, with the number of pre-tests per contribution (i.e., common ground prior to collaboration) as a covariate. In Study II, these analyses were done using a repeated measures statistical model to account for the two-session format. All analyses were performed with SPSS version 11. Due to no-show after the first experimental phase in Study II, the number of groups used in the statistical analyses was lower than 22. Data for 9 groups in the Idiosyncratic, and 5 in the Stringent conditions were eligible for statistical analysis. Because of the effects of such small sample sizes on statistical power we feel that reporting marginally significant effects ($.05 < p < .10$) is justified. Significant effects of phase I on phase II (effects of time) were not considered relevant to our hypotheses, and are not discussed here.

RESULTS

Study I

ANOVA revealed significant differences between the conditions for the number of contributions, $F(1, 10) = 12.27$, $p < .01$, number of verifications, $F(1, 10) = 13.72$, $p < .005$, and number of clarifications, $F(1, 10) = 7.25$, $p < .05$. In other words the Idiosyncratic teams made significantly more contributions, whereas the Stringent teams verified and clarified more often (see Table 3). Common ground was highest in the Stringent groups $F(1, 9) = 6.23$, $p < .05$ with common ground prior to collaboration as a covariate. Eliminating the non-significant ($p = .56$) covariate from the model resulted in a significant main effect from condition $F(1, 10) = 7.14$, $p < .05$.

Table 3. Negotiation Primitives and Common Ground in Study I

	Condition			
	Idiosyncratic ($n = 6$)		Stringent ($n = 6$)	
	M	SD	M	SD
Contribution	8.0	1.27	5.0	1.67
Verification	8.8	4.36	16.7	2.81
Clarification	10.7	4.50	17.7	4.50
Elaboration	56.6	22.42	48.5	21.52
Acceptance	3.0	2.10	1.8	2.14
Rejection	1.2	.98	1.7	2.73
Agreement	8.7	2.66	11.7	7.74
Disagreement	1.3	1.21	2.0	1.41
Regulation	30.7	22.52	43.7	17.18
Other	8.0	8.92	5.0	4.47
Common Ground	1.97	1.90	2.39	.33

Study II

Repeated measures ANOVA tests revealed a significant interaction between time and condition for the number of verifications, $F(1, 12) = 8.28$, $p < .05$. In both sessions, Stringent teams made more verifications than Idiosyncratic teams, but in the Stringent teams' afternoon sessions have less verifications than morning sessions, while in the Idiosyncratic teams it is the other way around. Noteworthy marginal interactions were the number of contributions, $F(1, 12) = 4.37$, $p = .06$ and the number of elaborations, $F(1, 12) = 4.38$, $p = .06$. Both figures dropped quite markedly between sessions in the Stringent groups compared to the Idiosyncratic groups.

Noteworthy marginal main effects were revealed for the number of verifications, $F(1, 12) = 4.35$, $p = .06$, the number of clarifications, $F(1, 12) = 4.56$, $p = .05$ the number of disagreements $F(1, 12) = 3.75$, $p = .08$, and the number of regulations, $F(1, 12) = 3.86$, $p = .07$. These figures were highest in Stringent groups (see Table 4). In other words, the marginal effects suggest a trend in the expected direction, that is, more verifications and clarifications in the Stringent teams. Unexpectedly, common ground was highest in the Idiosyncratic teams $F(1, 11) = 7.83$, $p < .05$ with common ground prior to collaboration as a covariate. Eliminating the non-significant ($p = .80$) covariate from the model resulted in a significant main effect from condition $F(1, 12) = 8.46$, $p < .05$.

Table 4. Negotiation Primitives and Common Ground in Study II

	Condition							
	Idiosyncratic (n = 9)				Stringent (n = 5)			
	Morning		Afternoon		Morning		Afternoon	
	M	SD	M	SD	M	SD	M	SD
Contribution	6.22	1.99	4.89	1.90	7.20	2.28	3.80	1.64
Verification	1.22	1.30	1.67	1.80	4.80	2.28	2.00	2.83
Clarification	1.89	1.97	.78	.67	3.60	1.67	2.40	3.21
Elaboration	27.44	16.36	27.11	14.43	46.00	23.05	20.40	18.15
Acceptance	1.56	1.13	1.33	1.32	2.00	1.58	2.60	2.41
Rejection	.44	1.01	.00	.00	.80	1.10	.20	.45
Agreement	3.33	2.78	4.44	2.96	3.80	3.27	2.80	2.39
Disagreement	.44	.73	.44	.73	1.40	.89	.80	.84
Regulation	27.22	20.57	25.00	20.54	48.20	18.87	43.80	15.37
Other	28.89	31.16	70.33	68.02	72.40	58.22	112.00	46.35
Common Ground	1.90	.65	2.02	.61	1.41	.39	1.55	.41

CONCLUSIONS AND DISCUSSION

This research studied the relationship between negotiation, the negotiation formalism, and coercion, with the ultimate goal being to design an ICT environment that facilitates knowledge construction. The main approach was the design of a formalism for the facilitation of common ground, which appears to be a prerequisite for knowledge construction.

The results showed that the two versions of NTool differed with regard to negotiation and common ground. In both studies, coercion was shown to increase negotiation, as hypothesised. However, with regard to common ground the results are contradictory. Whereas high coercion was associated with high common ground in Study I, the idiosyncratic groups were shown to have the most common ground in Study II. Analyses showed that the Idiosyncratic groups made significantly more contributions than the other versions. This may mean that the range of topics was widest in the Idiosyncratic version, which could suggest a trade-off between topic range and common ground. However, it may also be the case that participants in the Stringent versions, knowing that they had less opportunity to post contributions, chose to word their contributions more broadly, in which case fewer contributions would still cover the same topic range. Further, more qualitative research may shed some light on these explanations.

Disruption of collaboration (Dillenbourg, 2002), which can be caused by over-scripting collaboration, may explain some of the results. The need for more regulation in the Scripted version (Study II) may have caused some disruption in task performance. In that respect, the marked drop in contributions and elaborations in the Stringent afternoon sessions and the lack thereof in the Idiosyncratic groups, may indicate a loss of attention to the task in the Stringent groups that may have not occurred in the Idiosyncratic groups. This might show that using NTool was quite taxing in Study II. In Study I, where participants were university students, no such differences were observed. In sum, NTool influences both negotiation of common ground and common ground itself, and does so increasingly as coercion increases. The Stringent version may have caused some disruption in Study II but not in Study I.

The results are promising with regard to the facilitation of the grounding process, but they also indicate some limitations in the applicability of such facilitation. In her study, Barron (2003) showed that interaction is important for problem solving, and that engaging in each other's thinking was related to better solutions. The present study has shown that ICT-tools can be used to facilitate such interactions, by using a formalism for negotiation, and coercing the user into following it. However, these results were more easily achieved in the laboratory than in a secondary vocational education institution. Whereas in Study I all expected effects occurred, in Study II some unexpected effects occurred as well. This shows that the ultimate implementation of a tool like NTool should be weighed against the expected benefits, and the capacities of the intended audience.

More research is required to test our ultimate aim of facilitating complex problem solving. The present study does argue a relation between common ground and the quality of problem solutions, but does not explicitly measure it. Overall, it can be concluded that NTool and its underlying framework affect negotiation of common ground, and that adding some coercion increases this effect. However, one should be careful with the specific task and audience before implementing NTool.

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Improving the Coordination of Collaborative Learning with Process Models

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Abstract. CSCL is seen as a socio-technical process which has to be carefully planned by both students and teachers. These processes can be presented as graphical models which serve as maps to guide the students through their collaboration. In an experimental field study, the participatory development of these models was compared to a condition without models. The data shows the advantages of graphical models for the students' planning coordination. Most of the five hypotheses are confirmed in this study. These findings show just how important a technical concept is which helps to integrate the developed models as a means of coordination and navigation into CSCL-systems.

Keywords: Coordination, graphical process models, maps, representational guidance

INTRODUCTION: THE NEED TO SUPPORT STUDENTS' COORDINATION

It is an increasingly common finding in CSCL and CSCW studies that CSCL is a socio-technical process which requires careful planning and preparation by both students and teachers. In several experiments with CSCL for seminars conducted at a university, we learnt that the effort needed to be put into this preparation is often underestimated. Our approach was to offer the students a platform with which they could coordinate and mutually prepare presentations. We pursued a concept of blended learning where students present the results of their research in face-to-face sessions, while the research itself is organized as teamwork. The teams of three students used a web-based system to collaborate. We tried to initiate learning processes by deliberately designing tasks which were able to motivate the students in collaborating and sharing their results. They were asked to integrate their differing findings and perspectives and produce a single document. We have worked with platforms such as BSCW (Appelt & Mambrey, 1999), LiveLink™ (Opentext) and KOLUMBUS (Kienle & Herrmann, 2003) which can be used to exchange documents, web-links, comments etc. In our first experiments we focused on giving the students instructions as to how they could interact with the system and then expected them to develop their own way of collaboration. However, we learnt that this kind of preparation was insufficient and that our expectations were not fulfilled.

We could observe a number of problems which arose in this kind of setting that had similarly also been found by other authors (Guzdial & Turns, 2000, Lipponen et al., 2002):

- The interaction between students and the sharing of knowledge was poor. They split the task into independent parts instead of collaboratively working on it. Statements, questions, comments etc. from different students were not really interrelated or presented in integrated documents. Thus, there was a poor convergence of the students' perspectives (Stahl & Herrmann, 1999).
- The students did not use the system as intensively as was expected. Many of the system's possibilities remained unused.
- The use of the systems didn't really improve the teams performance.
- The expectation that the students would be able to organize their collaboration themselves while using the system was not fulfilled.

Our explorative studies showed that those aspects of the learners' tasks which refer to the process of computer-mediated collaboration were often neglected. We could say that the more the learners focused on the content of their task, the more they lost their awareness of the process of collaboration and the possibilities that the technical system offered. We came to the conclusion that we can not study the effect of computer support on collaborative learning before we have a method that ensures that intensive collaboration and usage of the system takes place. We can therefore see that supporting the students to plan their process of collaboration on their own will be a major success factor. This is based on the assumption, that CSCL not only covers content-oriented learning but also process-oriented learning. Fig. 1 shows the different stages of preparation for CSCL.

The rectangle shows the main focus of research in this paper. The focal point implies that the students learn how to organize collaboration, and that they gain a meta-cognitive understanding of what they will be learning, and how they will be learning it. It also includes an increased awareness of the collaboration process and of what problems could arise.

While the definition of the task and its presentation can mainly be carried out by teachers, the plan of the collaboration process has to be developed by the students themselves as opposed to being delivered to them. This is due to supporting self-directed learning and learning "how to learn collaboratively". The planning of the collaboration and of the usage of the system should take place in face-to-face sessions before the system is used. The outcome of the planning phase can be a graphical process model which guides the further process of collaboration.

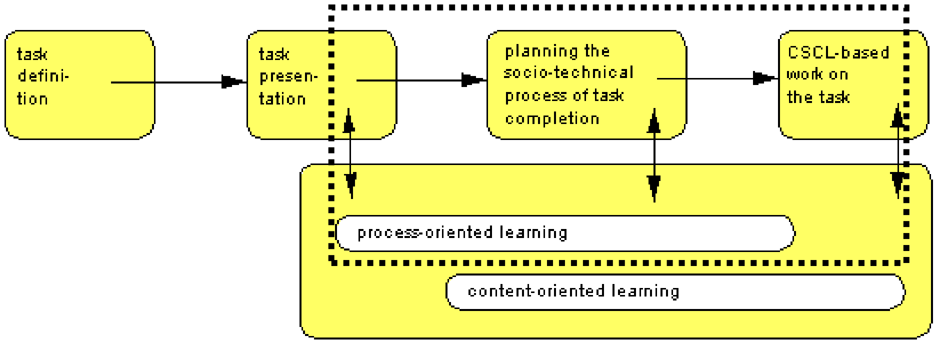

Figure 1: The focus on process-oriented learning

The effects and the appropriateness of this kind of process model in supporting a smooth collaboration can be compared with other concepts (cf. section "Related Work"). This comparison as well as our explorative CSCL-studies led us to the proposal that students should develop graphical process diagrams as maps which guide them through the technically supported collaboration.

This proposal is based on our research during the last seven years when we explored the role of graphical models in supporting collaboration in work and learning. For this purpose, we have developed an appropriate modeling notification, an editor which supports it, and "the socio-technical walkthrough" as a participatory method in applying these tools. Now we have the basis to systematically investigate the possible effectiveness of model building as a preparatory stage in CSCL curricula. In this paper we start with a field experiment which provided statistical evidence of the strengths of process maps and the socio-technical walkthrough by contrasting them with text based instructions (sections "Method" and "Results"). This finding justifies further elaboration of a technical concept which integrates process models as maps for collaboration into the CSCL-system itself (section "Conclusion"). Future tests will show how the improved planning has an impact on the collaborative process, the task accomplishment and the learning.

RELATED WORK: PROMOTING THE COORDINATION OF COLLABORATIVE LEARNING

In CSCL research, four main concepts of supporting group coordination and collaborative learning are discussed. These are: *cooperation scripts* (Dillenbourg, 2002), *maps* (Wang et al. 2000), *scaffolding* (e.g. Weinberger al., 2002, 2004), and *feedback* as a strategy of coordinated intervention (Zumbach and Reimann, 2003). In this article, we focus on the difference between scripts and maps and their potentials for guiding groups through the process of planning and carrying out their computer supported collaborative learning process. These concepts are closest related to process modelling as we have analyzed them in this paper.

Following Dillenbourg (2002, 64), a *collaboration script* can be described as "a set of instructions prescribing how students should form groups, how they should interact and collaborate, and how they should solve the problem." Numerous approaches can be summarized under the term cooperation script. With respect to speech act theory (Austin, 1955), some solutions implement posting of categories in the learning environment to promote the knowledge building group interaction. For instance, Baker and Lund (1997) use a structured communication interface containing a set of communication act buttons ("I agree", I propose to…", "Do you agree?") in order to facilitate an easier understanding. The buttons are grouped in categories according to their communication function (e.g., "construct a knowledge chain", "come to agreement", "manage the interaction"). Ludvigsen and Mørch (2003) used different categories of inquiry (e.g., problem, deepening knowledge, reliable knowledge, meta-comment) which are seen as relevant for scientific inquiry but also helpful as problem solving guidelines. In their approach, students had to select a category of inquiry each time they posted a message.

Generally most of these script approaches are more or less related to supporting content related group discussion but are not designed to promote the learning *process* itself. Therefore, Weinberger et al. (2002, 2004) suggested a differentiation between content related (epistemic scripts) and cooperation related scripts (social scripts) to enhance the learning of the process of problem based learning. In their approach, the former were based on content related questions or on a cloze which has to be answered or filled in and thereby leads the students through the learning material. The latter assigned the student two different roles, viz *analyzer*, who has to analyze the material accurately, and *reviewer*, who has to prove the arguments of the analyzer and find both inconsistencies and gaps in the argumentation. Their results showed that social scripts can enhance individual acquisition of knowledge, whereas epistemic scripts apparently do not to lead to expected outcomes. Indeed, there is not yet an evidence that social scripts are suitable for learning and internalizing *the process* of collaborative learning in such a way that learners are able to transfer this process to other learning situations in a self-directed way.. Another script related approach focussing on the process perspective of collaborative learning is the learnflow system designed by Wessner et al. (1999). They designed a process orientated script by predefining sequences of actions which are built into the learning system like a learnflow. However, this learnflow approach neglects the articulation work, collaborative learning needs to make the "flow" happen (Schmidt and Bannon, 1992). Resumptive scripts are rather restrictive, implemented in the CSCL-system, prepared by the teacher and only allowing only one predefined solution of how the learning process should be carried out. However, particularly in problem solving situations there is usually more than one way of performing the collaborative learning process. Therefore, these script implementations are hardly suitable in supporting students to plan and carry out their collaborative learning process in a self-directed manner.

In contrast to scripts, our conclusion from the literature is that maps (as a form of graphical process models) are more suitable in supporting the collaborative learning process because they are "inherently vague" (Suchman, 1987). Following Schmidt and Bannon (1992, 25) it can be said that "any non-trivial collective activity requires effective communication that allows both ambiguity and clarity". On the one hand, maps presuppose a plan of the required activities, the agreements about who is doing what with whom, and the resources needed, but they do not represent these practices and circumstances in full detail. With all respect to promoting self-directed learning and the building of a mutual understanding of the learning process, maps could be developed at the beginning of the learning process jointly by the students rather than being provided by the teacher.

Wang et al. (2000) designed a map orientated approach "supporting teams in the description and definition of processes, the learning of these processes, and the adaption and execution of these processes" (p. 358). A directed graph underlies their hypermedia based approach. The nodes represent tasks and the edges represent the coordination structure between the tasks. Wang et al. (2000) provide a shared hypermedia workspace in which users can access shared and persistent objects (nodes and links). Tasks (nodes) and the connections between tasks (edges) can be manipulated either synchronously or asynchronously by the students. Different node types can be edited by using different type-specific interaction tools. The advantage of this approach is that students can design their learning process collaboratively and self-directed. However, in our opinion students have to be supported in planning this process because of their lack of experience in both, problem based learning and self-directed learning. Furthermore, the aspects which are presented in the graphs should not only cover the process of collaboration but also the usage of the technical system and its integration in this process – this means to follow a socio-technical perspective.

Our approach is to intensify the students' reflection of how to carry out their task collaboratively. Our suggestion is that this intensification can be achieved by using the following strategies:

1. CSCL has to be considered as a socio-technical process where the interaction between the students and the application of technical means is highly interwoven (Herrmann 2003). This socio-technical perspective should guide the planning of the students´ collaboration processes.
2. It reveals that it is disadvantageous to confront the students with completely finalized plans of collaboration. In contrast we suggest a participatory approach where the students can themselves develop a plan of how they want to work together and use the system. This strategy was inspired by the idea of transferring the methods of the participatory design of software systems (for an example Kensing et al., 1998) with the design of a socio-technical system as a whole (Herrmann et al., 2004). The students' sessions, where they planned their cooperation, were facilitated, that means that the socio-technical process was developed step-by-step following a concept which we call socio-technical walkthrough.
3. Those parts of the task which refer to the socio-technical process of collaboration should not only be described textually, but also provide models which represent the interaction between the students and between their activities, as well as the computer system including computer-mediated communication. These models can be seen as maps.
4. The task description should be permanently available and brought to the students' attention. This requires textual descriptions and process models being permanently available on the system. To enable seamless integration of perception of the process models and use of the system, we suggest offering these diagrams as a

means of support awareness, which navigate the way through the learning material and guide students' contributions. These function as a navigational aid emphasizing the role of the diagrams as representational guidance.

5. These strategies were found by using explorative investigations in field studies where computer-mediated communication and document exchange were used to support collaborative learning. Subsequently we analyze our assumption of the usefulness of graphical process models in an experimental setting.

EXPERIMENTAL FIELD STUDY: THE RELEVANCE OF GRAPHICAL PROCESS MODELS

Setting

We conducted our experimental field study to test the assumption that **preparing the collaboration with the help of graphical process models leads to better results than when just working with text.** Our notion of *better* refers to the degree of using the system and of exchanging and integrating knowledge. The study was embedded in a seminar "consequences of information technology" at the University of Dortmund (Germany) in winter term 2003/2004. 24 students participated in the seminar (21 male and 3 female). In the seminar, groups of three students had to prepare a presentation and a thesis/paper upon given topics. Therefore subtasks like collecting material, preparing a table of contents, a reciprocal review of developed material had to be carried out. The students had access to the system LiveLink™ to support and document their collaboration.

The experiment was related to the seminar's phase of reciprocal reviews in which two group members had to give a (written) review to the other student about her/his prepared presentation. For the experimental field study the following setting was arranged:

- Eight groups of three students took part in the study. Each group met in a 1.5h face-to-face session.
- In the session, each group had to develop a detailed plan at the process of collaboratively writing reviews.
- The sessions were moderated. Therefore two moderation methods were used: a traditional method using traditional visualisation aids (meta-plan, flipchart) and the socio-technical walkthrough which uses graphical process models (socio-technical walkthrough method, c.f. Herrmann et al. 2004). In the following these two methods are named as the condition "without model" and "with model". Due to our small sample, we neglected to compare the condition "with model" with a third condition "without moderation". This consideration is further underpinned by our teaching experiences which led us to the assumption, that students have to be supported while planning their collaboration. The participants were randomly assigned to the conditions. The two conditions did not differ by gender. 4 moderators were involved. Each moderator facilitated a session in each condition to reduce the influence of his/her characteristics on the experiment.
- Preliminary to the session, each group of students received the same detailed instructions about the task and disjunctive information about the system LiveLink™, and organizational aspects. Therefore, one student did not know the same aspects of technical and organizational conditions as the others in her/his group. The students should discuss these aspects in the session, but they were not allowed to bring the instructions into the session. The disjunctive instructions were given to the students to allow us to observe the exchange of information during the discussion. To collect data on the information exchange, all participants were asked to complete questionnaires both before, as well as after the session.
- In developing the plan of the collaboration process, the groups had to reflect on how the system LiveLink™ could be used in preparing the reviews. The students developed possible plans as to how to proceed and discussed how the system LiveLink™ could be used. The students agreed on a plan which covered certain aspects such as deadlines and responsibilities. In the condition "without model" the results were summarized in checklists (as a kind of text, e.g. a "To Do"-plan on the flipchart, see fig. 2). In the condition "with model" the result was a graphical process model (see fig. 3), which was produced with the help of an editor.[1]
- After the sessions, the students started to work on their reviews which had to be finished within one month.

[1] We have carefully considered the question whether the usage of a computer system under the condition "with model" would influence the results. However, in our opinion there are no disturbing effects, as firstly only moderators used the system, and – in the without model condition – the moderators produced a clearly readable text documentation of the students' contributions. Secondly, the participants in both conditions were computer science students who had frequently worked with computer systems. Since computer science students are more familiar with modeling methods than people with another background, it should be mentioned that a simple modeling method was used which has proved as easily understandable (Herrmann et al., 2004).

Assumptions and Hypotheses

Our assumption was that the usage of models during the preparation of the collaboration leads to better results (in comparison to the usage of checklists). Better results are operationalized by:

Knowledge exchange: We assume that focusing on process models leads to a better knowledge of the collaboration process (in comparison to the usage of checklists). This assumption supposes that process models enable a structured presentation of exchanged knowledge. This presentation conveys the communication of both aspects – the CSCL-system and the process of cooperation. Our hypothesis is that:

Hypothesis 1 (H1): *Students in the condition "with model" mention more aspects which are part of others' given instructions in the questionnaire filled in after the session than students in the condition "without model".*

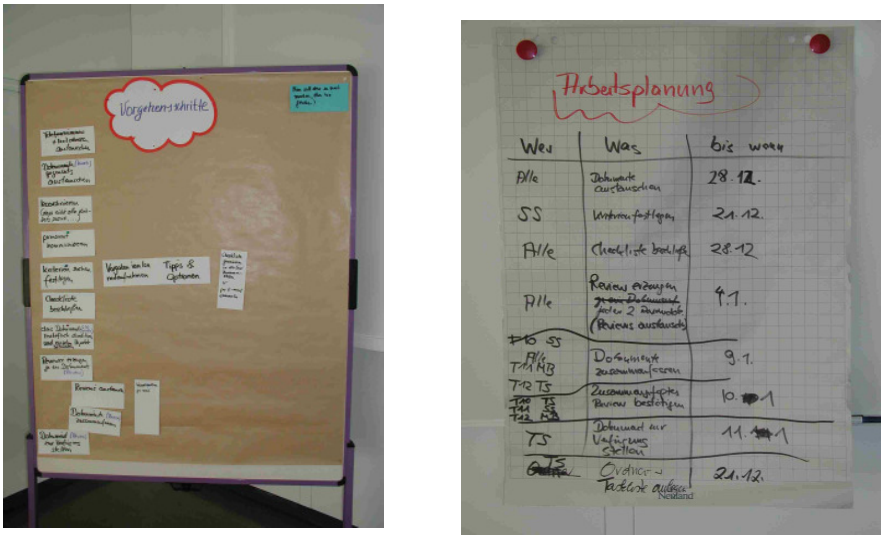

Figure 2: Visualization of tasks (left) and To Do-plan (right) in the condition „without model"

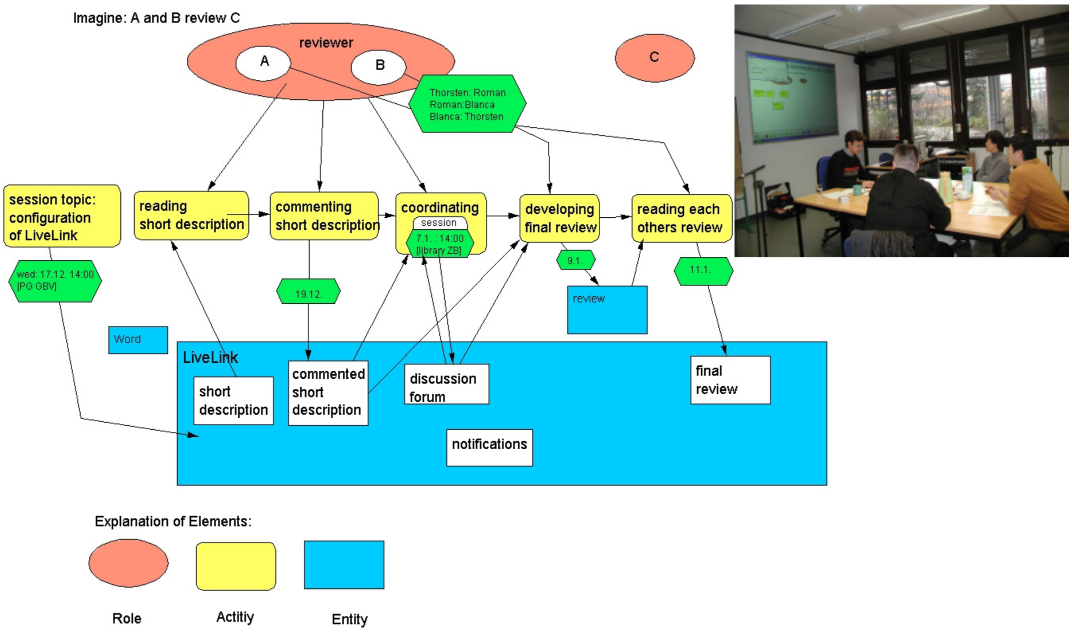

Figure 3: Example of a process model as it was developed during a session. The original text is translated. The explanations of the modelling elements have been added.

Integration of exchanged information during the group discussion in the artefacts: During the planning of the collaboration process, the group members exchanged their knowledge about the CSCL-system and how to use it. We assume that the planning discussions reveal differences with respect to the multiplicity of aspects which are found in the plans being developed during the group sessions. The number of all items contributed during the session can be seen as an indication of the complexity of the collected information that can potentially be taken into account when generating agreements for the collaborative process. These items are contained in the visualisation of the group discussion (text based vs. graphical process models). Although our experiment supposes that the condition "with model" leads to a better planning process, this assumption does not coercively imply that more items are collected under this condition. It could also be the case that the "without model" group produces a higher number of items which are superficial or may not be consequently used for the planning process. Therefore, the following hypothesis is non-directionally formulated:

Hypothesis 2 (H2): *The two conditions differ in the number of items which are contained in the visualisations of the plans.*

In addition, it is interesting to see how many commitments groups made using the collected information. A statement is a commitment when a specific cooperation task is assigned to a deadline or to a person. For example the agreement "task management has to take place in the system" is not a commitment in contradiction to "person B adds task in the systems on Monday". We were specifically interested in the commitments regarding the usage of the CSCL-system, as we wanted to encourage the usage of the system. The group can make its own decision as to how and if the system is used. We presume that the use of process models helps groups to organize their work. This means more commitments about the usage of the CSCL-system are made and collected pieces of information are more utilised. To test this assumption we a) identified how many commitments a group made in relation to all collected information and b) we identified how many commitments a group made regarding the usage of the CSCL-System. Our hypotheses are:

Hypothesis 3 (H3): *Taking into consideration all collected items there are more commitments in the condition "with model" than in the condition "without model".*

Hypothesis 4 (H4): *Within all collected items there are more commitments related to the use of the CSCL-system in the condition "with model" than in the condition "without model".*

Furthermore we expected that the groups in the condition "with model" would introduce more aspects about the socio-technical design into the artefacts in comparison to groups in the condition "without models". Such aspects relate to the functionality of the CSCL-system (e.g. tasklists or use of discussion forums) and the organizational arrangements for the use of the system (e.g. naming responsible moderators for discussion forums). Before the sessions the information about these aspects was given to the participants in the instructions. We hypothesize that:

Hypothesis 5 (H5): *In the condition "with model" more aspects related to socio-technical design are embedded into the artefacts, compared with the condition "without process model".*

Usage of the CSCL-system: We want the students to use the system in a self-motivated way and suppose we can encourage them to do so by means of using our specific approach. If the usage of process models leads to a better knowledge of the collaboration process in the group, it can be presumed that group members in the condition "with models" develop more common ideas about the cooperation process with the CSCL-system and that more binding agreements regarding the usage of the system were made. These should lead to a more intensive usage of the CSCL-system and the execution of joint tasks. We expect that these groups access the system more often and are overall more active users of the system. The usage of the system was measured by writing reviews during the collaborative work and thereby counting the logged events in CSCL-system. Furthermore, we analysed which functions of the system had been used by group members in the two conditions. We hypothesize that:

Hypothesis 6 (H6): *In the condition "with model" the number of logged events during the process of writing reviews is higher than in the condition "without model".*

Data collection

Data used to survey the knowledge exchange process related to the collaborative process was gathered in the pre-post-design[2] by means of a written questionnaire. The questionnaire we used to collect information about the

[2] Pre-post design means that the same questions have to be answered before and after the session.

system LiveLink™, how it was used for the preparation of reviews and the cooperation within the group. The questions were:

- How can your group use the LiveLink™ system to develop reviews?
- Which functions of the LiveLink™ system can be used to do this?
- Which agreements could be made within the team to help facilitate cooperation, as to how the system should be used?

The integration of exchanged information into the developed artefacts (meta-plan visualization, and ToDo-lists vs. graphical process models) was analyzed for the survey. Logfiles were analyzed to look at the actual use of the LiveLink™ system during the preparation of the reviews (after the group sessions).

RESULTS

Knowledge exchange

How often knowledge was exchanged was tested by comparing the numbers of aspects mentioned in the questionnaire. Table 1 and fig. 4 are related to the first hypothesis. They show group statistics for those aspects which were part of the instructions and were contributed to the group discussion. "Pre" means before the moderated session and "post" means after the session. There is no significant difference between groups pre-test-scores and the latter had no significant effect on post-test-scores ($B = 0.16$, $t = 0.87$, $p = 0.39$)[3] The analysis showed that the average number of aspects mentioned increased after the session in both conditions, whereas the value of post-test-score in the condition "with model" is significantly higher than in the condition "without model". We can conclude that in the condition "with model" the participants exchanged more information aspects amongst each other about the CSCL-system and work organisation than in the condition "without model". Consequently, hypothesis 1 is accepted.

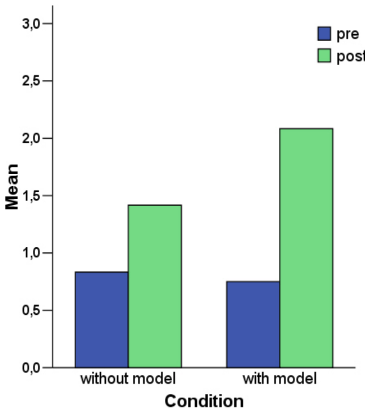

Figure 4: Group statistics showing the average of mentioned aspects

	without model		with model		t (df = 22)
	M	*SD*	*M*	*SD*	
pre	0.83	1.19	0.75	1.14	0.18
post	1.42	0.90	2.01	1.0	-1.72*
N	12		12		

Table 1: Group statistics and t-test statistics related to mentioned aspects; *p =< .05, one-tailed t-tests.

Integration of information into the developed artefacts

The integration of collected information into the developed artefacts was tested by analysing the visualised outputs (in checklists in the condition "without model" and in diagrams in the condition "with model") produced during the group sessions.

Variables	without model		with model		t (df = 22)
	M	*SD*	*M*	*SD*	
A (no. of general contributions to the discussion)	27.50	4.34	19.25	5.19	4.23***
B (no. of socio-technical design aspects)	8.25	4.14	13.50	2.39	-3.81***
C (quotient general commitments/contributions)	0.29	0.03	0.34	0.05	-2.61
D (quotient commitment LiveLink™ usage / contributions)	0.12	0.03	0.31	0.04	-13.53***
N	12		12		

Table 2: Group and test statistics of the variables on the output of group discussion; ***p<.001; A: Two-tailed t-test; B, C and D: one-tailed t-tests.

[3] Because the building of groups was randomised, a t-test for independent samples to compare the post-test-scores was used. Since the size of the sample is small, the pre-test-scores were compared and their effect on the post-test-scores were identified by covariance analysis. The independent t-test was chosen as there is no significant difference between groups pre-test-scores and the latter had no significant effect on post-test-scores.

It turned out, that the groups in the condition “without model” produced more contributions during the discussion than the groups in the condition “with model” (Variables “A”, table 2, fig. 5) (H2 is accepted). We conclude that the visualisations of the discussion in the condition “without model” contained more pieces of information and were more complex than in the condition “with models”. In contrast, the groups in the condition “with models” reached more agreements related to the CSCL-system, and at the same time utilised the collected information better, because of the fact that the number of commitments in relation to the number of all visualised discussion items was higher (variable “D”, table 2, fig. 5). This cannot be said of all commitments (variable “C”, table 2, fig. 5). If we look at all commitments, there is not any significant difference between the conditions (H4 is accepted, H3 is rejected). Furthermore it has shown that in the condition “with models” the visualised output covered significantly more points linked to socio-technical design than in the condition “without model” (variable “B”, table 2, fig. 5). Hypothesis 5 is accepted. If we look at table 2 we can conclude that the participants in the condition “with model” were more able to integrate the information (given in the instructions) into the group plans.

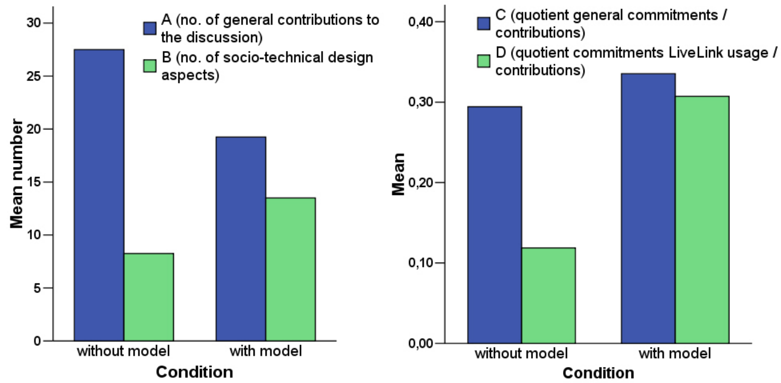

Figure 5: Group statistics of the variables to output of group

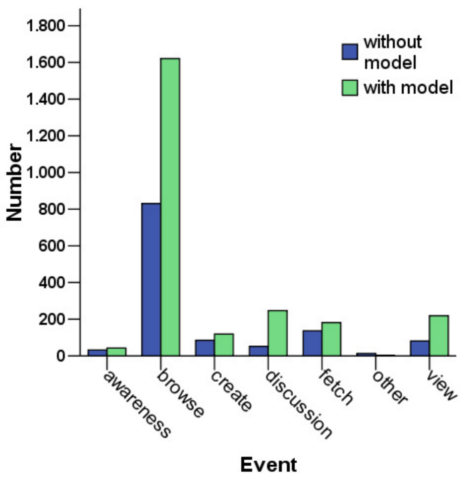

Figure 6: Number of activities in system

Usage of LiveLink™

The analysis of the logfile showed that the students in the condition “with model” were significantly more active in the CSCL-system than the students in the condition “without model”. The number of activities in the system in the condition “with model” amounts to 2433 and in the condition “without process model” it amounts to 1231 ($\chi^2_{(1)} = 394.32$, $p < .001$). Fig. 6 shows which activities this concerned. Fig. 6 shows also that the students in the condition “with model” were more active in almost all of these activities: They searched more documents in folders (browse), positioned more documents (create), downloaded more documents (fetch), viewed more documents (view), and were more active in the discussion forums (discussion), than the students in condition “without process model”. Hypothesis 6 is accepted. In this regard the students in the condition “with model” were using the system LiveLink™ intensively for their cooperative work.

Furthermore it should be mentioned that 22 students found the session used to plan the collaboration very helpful. They also regarded the moderation during the sessions as very helpful.

The presented results indicate that the condition “with model” leads to better results concerning the exchange of knowledge about the collaborative process. It also improves the development of commitments related to the use of the CSCL-System and the integration of learned content about socio-technical design in the cooperation plan. It also promotes the using of the CSCL-system better than the condition “without model”.

CONCLUSION AND FURTHER RESEARCH: INTEGRATION OF GRAPHICAL PROCESS MODELS INTO CSCL-SYSTEMS

The experimental field study presented in this paper revealed that the usage of graphical process models during the preparation of the collaboration can lead to more knowledge exchange and integration, as well as commitments concerning the collaborative learning process, and a more intensive and collaborative usage of the

CSCL-system. However, further studies will have to observe, whether the combination of an intensified collaboration process and working on a certain problem might cause a "burn out" effect for the students.

To test the influence of models on the CSCL-process our next step is the integration of the process models into the CSCL-system in order for them to be continuously available, and to serve as a representational guidance. Representational guidance means the design of a software system that enables the software itself to facilitate the collaborative learning (Suthers and Hundhausen 2002). To demonstrate the integration of coordinative process models, we use a CSCL prototype (KOLUMBUS, Kienle and Herrmann 2003). It supports collaborative learning by using an integrated view on communicative contributions (annotations) and material (text, multimedia elements). This content structure can be intertwined with such graphical process models as those developed in the sessions of the experiment.

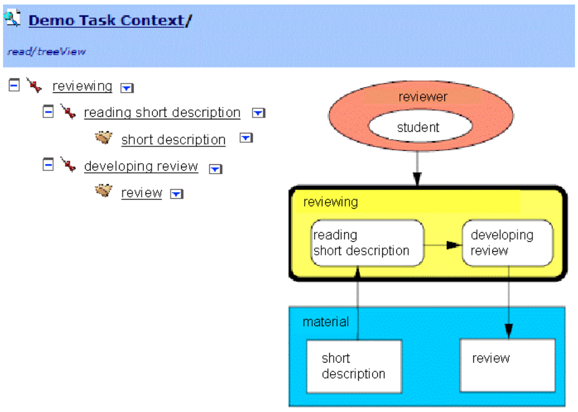

Figure 7: content structured by tasks

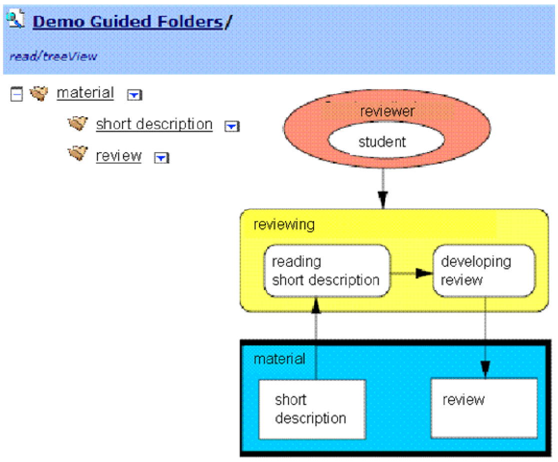

Figure 8: content structured by material

Our concept is that a model can be developed and modified with the help of an external editor (SeeMe-Editor), which then enables users to develop models with a semi-structured modeling notation SeeMe (Herrmann & Loser 1999). This editor has already been used in the sessions of the condition "with model" for our study. Because the semantic of the elements of the SeeMe-models can be consistently interpreted, the model itself has a guiding character and can be interpreted for the integration into the CSCL-System.

Before a model (as shown in figure 3) can be integrated into the CSCL-System, it has to be aesthetically improved. After this improvement, a specially designed import functionality offers the possibility of integrating the collaboratively developed SeeMe-model in all CSCL-systems which use XML like KOLUMBUS does. The model is used to structure a (sub-)area of the systems content. For example, for each activity in the process model, a task can be created and assigned. These tasks can be combined with a deadline and awareness mechanisms which indicate the progress of the task completion. For each entity, a folder is created which can be combined with a link to already existing material. When integrating the model into the CSCL-System, the user can decide, whether the sub-area should be structured in accordance with the tasks (see fig. 7) or with the material (see fig. 8).

After the import of the process model, an integrated view on the created (sub)-area and the graphical process model is presented (see fig. 7 and 8). This integration allows the students to use the model not only to prepare and plan the collaboration but also as an artifact (with underlying functionality) which accompanies the whole computer supported collaborative learning process: the graphical elements of the process model are linked to the folders, documents and statements which represent the learning material and discourses of KOLUMBUS. Thus, it will be possible to use the diagram to navigate through the content of the learning system and to relate the content to the planned and ongoing process. We assume that the continuous work with the model internalize their way of collaboration and increase the competence for self regulation. Our further research concerns an evaluation of the influence of these integrated models on the computer supported collaborative learning process.

ACKNOWLEDGMENTS

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AGQ: A Model of Student Question Generation Supported by One-on-One Educational Computing

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Abstract. One-on-one educational computing refers to 1 student 1 computing device, which means every student in a group uses a digital learning device. In this paper, we present a model of student question generation called AGQ, which stands for “asking a good question,” supported by one-on-one educational computing in the classroom settings. AGQ is designed for engaging students in a challenging learning activity that potentially involves higher-level cognitive processing operations. We shall describe the general design of AGQ, called Product Evolution, and that the current version is a variation of it.

Keywords: One-on-one educational computing, peer question generation, question posing

INTRODUCTION

Development of various forms of computing devices connected with wireless and wired network has advanced to a stage that these technologies have become an important part of learning environment for teachers and students (Weiser, 1998). Their advantages in supporting learning includes increasing availability and accessibility of information, engaging students in learning-related activities in diverse physical locations, supporting group work on projects, and enhancing communication and collaborative learning in the classrooms (Gay et al., 2001, Goldman et al., 2001).

One-on-one educational computing classroom (1:1 classroom) refers to a classroom in which every student uses a digital learning device, such as personal digital assistant, notebook, tablet PC, etc., to participate in learning activities. WiTEC or its subsequent DCE (digital classroom environment) system (Huang, et. al., 2001; Liu, et. al., 2003, 2002, 2003) are examples of 1:1 classroom that can potentially reduce time for the teacher to do tedious logistic work such as dispatching and collecting worksheets, grading quiz, recording teaching and learning processes as portfolios, engaging students in learning activities, enabling teacher to monitor student learning states, and facilitating group collaborative learning.

In this paper, we describe a CSCL model for supporting learning by asking questions in 1:1 classrooms called AGQ. We explain the rationales of its general design, called Product Evolution, which intends to make AGQ engaging, like a social game, while at the same time be able to elicit student cognitive operations. After delineating the technology support for AGQ, we discuss observations of a pilot study in a graduate course and future improvement.

AGQ: ASKING GOOD QUESTIONS

“Did you ask a good question today?” Isidore Rabi’s mother always asked, instead of asking “Did you learn anything in school today?” by others’ mothers. Rabi, a Nobel laureate in physics, credited this difference, asking good questions, as the reason why he became a scientist (Ciardiello, 1998). Einstein also mentioned “The mere formulation of a problem is far more essential than its solution, which may be merely a matter of mathematical or experimental skills. To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks real advances in science.” For emphasizing the importance of questioning, he also said, "Learn from yesterday, live for today, hope for tomorrow. The important thing is not to stop questioning." (http://www.brainyquote.com/quotes/authors/a/albert_einstein.html)

PRODUCT EVOLUTION METHOD AND DCC PROCESS

The essential learning is to engage students in the meaningful activities. Questioning is a valuable learning tool, not only for the answerer, but also for the questioner. It is important for students to create their own explanations of the information around them (Geelan, 1997). The activity of designing question and answer (Q&A) helps students retain and relate new information to prior knowledge. It gives students a chance to start to formulate answers by retrieving information from long-term memory. When students engage in the task of constructing and self-assessing Q&As they composed, students need to construct a question and build the answer corresponding to the question, indicate which part of the learning material is important and worth to test and clarify his comprehension of the learning material. In sum, questioning is a strategy to guide students to develop a repertoire of cognitive abilities (Balajthy, 1984; Ciardiello, 1998; Yu et al., 2002) – recall prior knowledge, search or inspect the learning material, identify the main ideas and concepts, make connections between them, and so forth. In this paper, we discuss the questioning in the situation which students design to test their peers.

Questioning can be of various modes (Gadamer, 1990). AGQ, which stands for "asking a good question," is the current version of a series of our effort in designing penetrating questions and evaluation of answers (Yu, 2004). AGQ adopts a cognitive conflict resolution process, called DCC process, consisting of three sub-processes, differentiated products, cognitive conflict, and common product. "Differentiated products" is a deliberate strategy for creating individual differences by summoning individuals to generate ideas, questions, articles, and so forth, which we term as products. In the case, AGQ encourages students to produce Q&As. This requires prior knowledge and creative thinking of individuals and because of uniqueness of individual past experiences, the products generated must be different in some aspects. "Cognitive conflict" is to put individuals together and demand them to develop some common consensus on their generated products. Because of the differences in their products, they have to explain, analyze, evaluate and discriminate their products. This sub-process commands critical thinking. Finally, "common product" calls for ability of modification and synthesis of their differentiated products into a common product.

Applying DCC, individuals generate their differentiated products. And then, small teams of a class are formed from individuals and finally generate their common products. If we apply DCC again, then larger teams are formed merging smaller teams in the previous round and the common product could in general be better than the previous one. We can repeat DCC process until the final round in which either there is only one team left, that is, the whole class, or the teams in the final round are competing teams and these teams participate in a contest for evaluating their final products. We call such a method of successively applying DCC as product evolution method (PEM).

Of course, there are various versions of PEM. According to the learning material, the teacher may assign types of questions based on the six categories of cognitive domain (Bloom, 1956). Also, PEM can be applied to other small group learning other than generating questions. For example, in the Reciprocal Teaching method (Palinsar & Brown, 1984) for text reading comprehension, a small group of students take turn for questioning, clarification, summarization, and prediction. Now, suppose we require a small group of 4 students, instead of having them all generate questions, every member has to conduct a different prescribed task, such as those described in Reciprocal Teaching. Then the product evolution method will become a variant of Jigsaw method.

CURRENT AGQ PROCEDURE

Since there are not many students in the graduate course for the pilot test, the current version of AGQ is a simple form of PEM and DCC is applied only once. There are five phases: (1) Teacher-led presentation of learning material; (2) Self-study of learning material and individual Q&A generation; (3) Q&A assessment; (4) Small group formation and conflict resolution; and (5) Teacher-led class-wide discussion. Noticed that the (2), (3), and (4) is a DCC process. To carry out AGQ, one or two class periods are needed.

We choose multiple choice questions as the form of our questioning since multiple choice question items are the most familiar type of questions for students. A multiple choice item includes a question stem, an exactly correct option and three alternatives. To construct a multiple choice question, a student has to design a question stem with clear and definite description, make an exactly correct option corresponding to the question stem and three alternatives with well-attractive description. In other words, they have to understand the concept involved in the question and the relations between the correct option and the other alternatives. And the orders of four opinions are needed to be well-arranged. Figure 1 below delineates the interface for a student to design a multiple choice question item.

After every student generates her Q&A, there is a reflection process. First, a student self-assesses her Q&A with a set of rubrics. Following that every Q&A is sent to two anonymous peer reviewers for peer-assessment.

This also means that every student anonymously reviews two Q&As from two other students'. Anonymous reviews are judged more critically than those made in the identifiable condition (Zhao, 1998). After that, all the mutual reviewers are told to form triads and now every student knows who two other students review her Q&A previously. The objective of each triad is to send two items for the class-wide discussion led by the teacher. They have to determine which two items to be sent from the three they have. In order to resolve the conflicts, each student in the triad has to elaborate, justify, or clarify possible confusions on the ideas of her own item, and correct the item according to her teammates' comments. They try to reach their best consensuses in this negotiation process—not just finish the task. Some revisions might be needed before sending them out. (Figure 2) illustrates the interface of the self and peer assessment form.

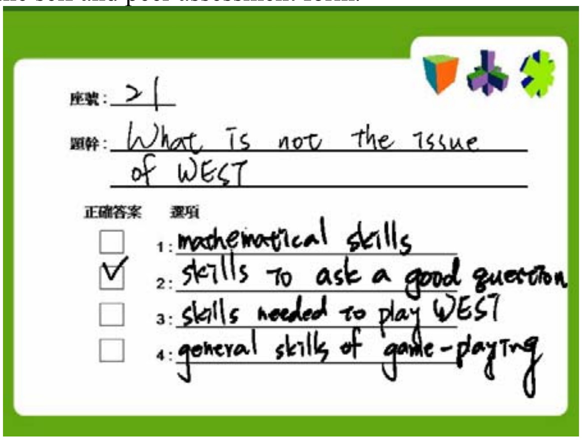

Figure 1. Work space of individual question design

In the phase of teacher-led class-wide discussion, every student has to answer and give scores to all Q&As from every triad. Teacher also scores for all the products with explanation, but possibly with weight different from a student. Viewing products from other teams broadens the horizon of their thought. Teacher points out if there are misconceptions and misunderstandings. Finally, the system sums up the scores given by students and the teacher. The teacher's role in this class-wide discussion is necessary for pointing out some common misunderstandings with clarifications and explanations in time for the whole class, avoiding the same misunderstandings to happen in the future.

Figure 2. Self-assessment and peer-assessment forms

Follow from that, every student has to answer all questions composed by other groups individually and then compares his/her answers with the answers given by others and then rank all the Q&As. The teacher also ranks all the Q&As with explanation. Based on the rankings by students and that by the teacher, possibly with different weights, the ranking of the teams can be decided.

ONE-ON-ONE CLASSROOM SUPPORT FOR AGQ

The information could be effectively transferred from the handheld network to social network in a mobile computer supported collaborative learning activity (Zurita et al., 2004). Advancement of technology enables CSCL to extend the traditional collaborative learning activities to include computing capabilities, offering new possibilities for achieving more effective and attractive learning activities. The emerging of mobile technology even provides the potential that every learner has her owned personal devices for participating learning activities all the time and at different locations. In such a mobile learning environment, it is easer for learners to exchange information and more social interactions allowed (Jansen et al. 2003; Zurita et al., 2003).

Integration of digital devices with wireless and wired network connection provides an environment for computer-mediated face-to-face interactions. This environment empowers the conflict resolution process when every member can look at what she has done from individual view or what they have done from the integrated view on demand with annotation facilities. The movements among students in the classroom are at ease with the support of wireless communication. It is also a simple task for the teacher to assign students into small groups and every member of a small group can generate their questions and answers in the AGQ procedure.

Without the support of the digital devices and related technologies, there are some tedious works to run AGQ using flash cards or papers. For example, a student needs a piece of paper to construct her question and answer (Q&A). After copying the Q&A with several pieces of papers for self-assessment and peer-assessment of the items, some more papers will be used in the small group collaboration. Dispatching papers is also a time consuming process. One-on-one classroom can address these problems and much easier for some logistic task. For example, in the anonymous peer-assessment process, system can distribute Q&As directly to anonymous reviewers in a second.

TRIAL TEST

A trial test of AGQ was conducted in a graduate course. There were twenty-one graduate students with Table PCs to participate in the experiment. Before starting the procedure of AGQ, a collaborative presentation of learning material was carried out by some students. And then, each student composed a multiple choice about the learning material as their learning task in the first phase. After the composing phase, each student had to anonymously assess two items composed by other students. Then, there are eight trials formed in the whole class to proceed the next phase. With the display of the results of the peer-assessment on their Table PCs, they discussed face-to-face to elaborate their evaluations, choose two items as their small group items and revise them before submitting. Next, two trials were formed as a large group. Four large groups were formed in the phase. The peer-assessments and item choosing were repeated again. Because of absences and the problems with the connection between a few devices and the server, only seven items were sent to the phase of class-wide discussion. It totally took two hours to finish the procedure of AGQ.

According to our observation, the activity was engaging and they participated in actively through the process. Unfortunately, because most participants were unfamiliar with the operations of the system, much time was spent on trying to find out how to operate the system correctly. Refinement of the system is needed for ensuring smooth run of AGQ procedure.

We note that questions generated in this experiment were mainly fact-based questions. Many stems of the items are excerpts selected from the important parts of the learning material. Students also use concepts which are titles and sub-titles of sections and subsections, respectively, in the learning material. Also, they adopted some sentences in the presentation given by the teacher at the beginning phase. We also noticed that there were substantial number of similar Q&As generated by different students in the experiment.

SUMMARY

AGQ is a model of CSCL testing how student learning can be enhanced in 1:1 classroom. The current version of AGQ applies PEM and involves one DCC process: individual Q&A generation, self-assessment and peer-assessment, small group conflict resolution and modifications to reach common consensus. Finally a teacher-led class-wide discussion enables students to have a global view of the learning material digested by the class. A trial test was performed with the system and some observations were discussed. In next round of study, we shall incorporate guided questioning strategy to facilitate student understanding of the material and encourage and scaffold them to construct higher-level questions, not just factual questions (King, 1992, 1997). And some evaluations will be conducted at the next stage, such as the students' perceptions of processing the procedure of AGQ and the use of the technology, how usefulness and effectiveness of the procedure of AGQ and the support of software.

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Effective Discussions, Social Talks and Learning: A Paradox on Learning in Discussion Forums

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Abstract. It is generally accepted that social talks have nothing to do with on-task discussion, or even that they are to be discouraged in the interests of effective learning. However, from a community-building perspective, social interaction is key to the sustainability of a learning community. An apparent paradox seems to exist in that, while social interaction is critical for community cohesion, social postings do not contribute to effective discussion. The authors argue that previous research using postings as the unit of analysis has failed to discover the context in which effective learning took place. Using threads as the unit of analysis, this study is able to explore empirically the relationship between effective discussion and social talks in CSCL environment. Based on an analysis of 321 longer threads (consisting of 10490 postings) in which the structure of the threads, the components of the threads, and the order of different categories of postings in some of these threads were defined, this study reveals that genuine effective discussions and social talks cannot be viewed in isolation nor does there exist a wall between them. The roles of social talks in CSCL are rediscovered and discussed.

Keywords: social talks, “off-task” interaction, effective discussions, thread

INTRODUCTION

CSCL is normally aimed at providing new opportunities for designing and implementing advanced learning, such as deep learning, sustained and critical discourse, and effective discussions (e.g., Guzdial & Turns, 2000). Current insights into the CSCL-environment also suggest that social interaction is important for a community that supports learning (e.g., Kreijns, Kirschner, & Jochems, 2002). It seems that both effective discussions and social interaction are the focus of learning in a virtual community. However, despite their respective importance in learning, there is little research on the relationship between effective discussion and social interaction.

A body of research does articulate the negative effects of social talks on effective discussion. Researchers have claimed that social talks fall into another category of activity, one which prevents students from learning effectively. For example, Hara and colleagues (Hara, Bonk, & Angeli, 2002) examining the relationship between cognitive processes and social cues in a study conducted on a graduate level course, reported that social cues appeared separately from content discussions and that the number of social cues decreased as the semester progressed. During later weeks, students engaged in intense online discussion and were highly focused on the task. They described social cues as taking a back seat to student judgment, inference, and clarification. Walther (1996) also argues that the more effective CMC is, the less socio-emotional communication is present. Similarly, some research done by exploring the percentage of on-topic and off-topic discussion concluded that the ratio of the two determined the effectiveness of learning. Lipponen and colleagues (Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2001) conducted an online science discussion with elementary students and reported the proportion of on-topic notes to be 63% with off-topic notes totaling 37%. They were disappointed in this ratio, having expected the discourse to be more oriented to the subject matter and practices of inquiry than it turned out to be. They sought a higher on-to-off topic ratio assuming that the more the discussions were oriented towards learning topics, the more students would learn. Furthermore, Badri, Grasso, & Leng (2003) developed a “filter” to distinguish relevant contributions from irrelevant contributions and to help instructors to identify students who constantly disrupted conversations with off-topic contributions. These studies all seem to regard effective discussion and social talks as existing in conflict with each other, the one, constructive, and the other, distracting.

There is also a body of research revealing the positive effects of social talks on effective discussion. Steinkuehler and colleagues (Steinkuehler, Derry, Levin, & Kim, 2000) were the few researchers to make an effort to code the “seemingly effortless social interaction” into categories. Based on their data, “off-task” discourse was placed into four coding categories: housekeeping statements, social talk, tangent topics, and "null" statements. They found that the majority of off–topic content appeared to consist of social talk. Both housekeeping statements and social interaction were considered necessary to keep the general conversation on task, to maintain an amiable conversation, and to serve as a base to insure that participants understand one another. Furthermore, Hobaugh (1997) emphasizes that problems with social dynamics among group members are often a major cause of ineffective group action. Gunawardena (1995) claims that these kinds of "failures tend to occur at the social level far more than they do at the technical level". Their findings revealed the value of social interaction to effective discussion.

From a community perspective, the position of social talks in discussion forums was illuminated further by Wegerif (1998) who pointed out that: "Many evaluations of asynchronous learning networks (ALNs) understandably focus upon the educational dimension, either learning outcomes or the educational quality of interactions, overlooking the social dimension which underlies this." He noted that "forming a sense of community, where people feel they will be treated sympathetically by their fellows, seems to be a necessary first step for collaborative learning. Without a feeling of community people are on their own, likely to be anxious, defensive and unwilling to take the risks involved in learning". Rourke (2000) found that certain conditions must exist before students will offer tentative ideas to, or critique the ideas of peers, and before they are willing to interpret criticism as valuable rather than as a personal insult. These findings suggest that group cohesion is required for effective discussion.

Moreover, research also attempted to explore the context of "off-task" on the effectiveness of "on-task". Erickson & Kellogg (2003) investigated the content of conversations and concluded that "In theory, more topic-oriented discussion is 'supposed' to take place in specific topics; in practice, work talk often grows out of social discussions." Kreijns, Kirschner and Jochems (2002) concluded that, although social interaction in the social-psychological/ social dimension has little to do with task execution, we expect that various non-task contextual settings will foster this dimension of social interaction more than a task context would.

The investigation of this study aims to provide a better understanding of how learning takes place in online discussion forums through exploration of the relationship between effective discussion and social interaction. By examining the activities of learners in discussion forums, we attempt to trace the trajectories of online group learning.

THE RESEARCH QUESTIONS

The research on the relationship between social interaction and effective discussions is, however, anecdotal and speculative, rather than empirically grounded. The authors in this study approach the underlying structures between these factors with two methodological considerations. First, most of the research done on computer-mediated discourse analysis considers postings as the unit of analysis (Drie, Van Boxtel, Erkens & Kanselaar, 2004). Using this criteria, all of the postings are sorted into different categories according to their attributes. Postings are therefore isolated from each other and the context of the dialogue in which they appeared is missing entirely. However, in a threaded discussion, postings exist within a contextual atmosphere and a posting cannot be fully understood merely by the content of the single posting itself. Better insight into effective discussions can be gained from a macro-view of the threaded context.

Secondly, definitions of "effective discussion", as applied to performance in discussion forums, vary a good deal. The term "effective discussions" is widely and variously used to characterize positive group learning. For example, Guzdial & Turns (2000) applied the term "effective discussions" to discussions sustained and focused upon topics related to class learning goals. Hsi & Hoadley (1997) used "productive discussion" to refer to situations in which all students "participate actively, generate comments containing a repertoire of scientific ideas, and in a group, students elaborate their own ideas, and propose new ideas." It appears that what they call "effective discussion" referred to "cognitive" , "on-topic" , "on-task" , and "sustained" learning processes and clearly excluded the "off-topic" , "off-task" , "social interaction", and "social talks" activities. Must effective discussions be sustained and be on-topic? Who determines whether the discussion is "effective"? Whose perspective is being used?

Our question, then, is how to identify "effective discussion" from the perspective of the learners themselves, which data may then be used to explore empirically the relationship between effective discussion and social interaction. In this paper, we argue that isolated postings in discussion forums cannot serve as the unit of analysis for defining a picture of effective group learning. We introduce our tool, "Pick-n-Choose", with which learners identify the important posts in the threaded discussions of their joint tasks. Using the thread as a unit of analysis instead of discrete posts, we demonstrate how an effective thread containing identified important postings is structured, composed, and developed by interwoven postings in the three categories: task, coordination, and social talks. Our discussion focuses on two facets: rediscovering the "social talks" aspect of discussion forums, and identifying the effective discussion that takes place in "social talks". Through this examination, we are able to deepen our understanding of "how learning happens in discussion forums".

METHODS

The community & the tasks

The online community was formed for a web-based science contest in an inquiry-based learning environment called Learning Atmospheric sciences via the Internet (Lain), which was created primarily to allow high school students to participate as a virtual summer camp. Those volunteer individuals who chose the same topic from a list of five topics were sorted into a set of groups of 5-7 individuals each. Members of a single group did not normally know each other, nor did they engage in face-to-face communication throughout the activity. This web-based science contest lasted six weeks with one stage scheduled for each week. The six stages were: Individual claim formulation, Team hypothesis creation, Detailed planning, Data location, Data transformation, and Hypothesis justification. Participants in this activity qualified for a certificate if they went through the process and completed all required tasks. However, as there were multiple summer programs from which to choose and some participated in more than one, some students were absent for a few days, more or less, during the six week course.

The "Pick-n-Choose" tool in the discussion forum

Much research effort has been put into designing scripts or scaffolds to support effective discussion. Scripted encounters may work because they allow learners to push for deeper understanding and eliminate extraneous fruitless activity but this also raises the issue of over-scripting. For example, the self-coding activity (note-type or classification) may result in bored and faked entries. The "electronic anchor" , a document or topic which students may be interested in discussing (in CaMile discussion forum), is designed to elicit sustained discussion. However, we are still not in a position to judge whether it is "who", "what topic" or "when the statement is posted" that attracts people to join the discussion forums.

"Effective discussion" in previous research has been studied but only loosely defined (e.g., sustained, on-topic, on task…). In this study, we introduce the concept of "Important Posting" (IP), that which is identified by the learners as important and useful for later discussion, and "Important Thread" (IT), that which provides the environment within which the "IP" appears in order to empirically capture the context of important learning moments as "effective discussion."

Each group had its own discussion forum and permission to post in group discussion forums was restricted to the legitimate group members. They were read-only to non-members. The discussion forum was composed of threads, each a mini-discussion, triggered by the group's members. There were four prompts in each week's worksheet. Worksheets were designed around the scientific process skills at each stage of the week in order to anchor the discussions. As many community members were absent for short periods, and there were a vast number of threads and postings, the authors designed a "Pick-n-Choose" process for the following purposes.

The focusing features.

The focusing features helped group members to focus upon specific important elements among the dozens of threads. As the group was formed virtually, members of the group had to take an active role in building a shared mental model for the collaborative project. Any group member had the right to choose the posting that s/he thought important, and put it in a "Pick-n-Choose" collection. Later on, when working on the worksheets, completing their group tasks, and generating their final products, they had that shared mental model upon which to focus.

The Meta-cognitive features.

Differing from some of the self-coding interfaces in which learners were asked to classify every single post of their own dialogue (Dillenbourg, 2003), the "Pick-n-Choose" process was carried out only after the statement had been posted and whenever necessary. Therefore, not every single post had to be coded. This variation would not reduce the meta-cognitive and the methodological advantages of that approach.

The portfolio features.

One promising outcome of this process emerged. A troublesome paradox exists when the quality of the discussion process seems disconcertingly inconsistent with that of the final product -- when, for example, the discussions are sustained and on-topic, but the final products are poorly presented, or the final product is fascinating but there is little corresponding evidence in the discussion process. This presented problems in the evaluation process. "Pick-n-Choose" was designed to overcome this difficulty by requiring group members to choose important discussion segments from among the postings thus causing the artifacts to be more closely related to the final products.

The Sample

The four hundred and eighty seven (487) high school students who participated in this activity were sorted into 82 groups of 5-7 individuals each. The six-weeks of inquiry-based online discussions consisted of 42567 total postings in 7037 threads. The number of postings and threads produced by the groups averaged 519 and 86 respectively. The average number of postings in each thread was 6.8. Of these postings, 7943 (19% of the total) were included in the "Pick-n-Choose", "Important Posting" (IP) collection. The number of Important Threads (ITs) containing IPs, was 2220 (30% of the total). In order to explore the underlying structure of the more sustained ITs, we first chose the top 25% of groups (by thread length -- the number of postings per thread) and then from among these, chose the IT threads that were above the average (68%) (we will analyze the remaining 32% of ITs that were not "sustained" in another paper). As a result, 321 threads containing 10490 postings (of which 2688 were IPs) were selected as the sample for further investigation.

This is an environment designed for asynchronous discussion. However, due to the popularity of MSN Messenger, some of the groups communicated with each other in a synchronous way, as in a chat room. In this particular context, both real-time and delayed, spontaneous discussion and considered postings were documented and recorded.

Data analysis

In order to explore empirically the relationship between effective discussion and social interaction, this study developed a "Pick-n-Choose" tool for learners to identify the IPs and the ITs. The 321 ITs in our sample were first analyzed in the following ways.

Identifying the positions of the IPs within their ITs

The purpose of this analysis was to reveal the position of the IPs in each IT. Since probably more than one posting were designated as IP in an IT, we arbitrarily divided all the threads into 3 sections: the Beginning part, the Middle part, and the Closing part. A frequency count was kept of postings which fell within each part. Our assumption was that if an IT was socially constructed, the IP would appear in the Closing part. On the other hand, if an IP appeared at the Beginning or in the Middle part, then what took place after the IP? In other words, from a knowledge-building perspective, an IP would be expected to emerge from the latter part of a thread. That is what a "meaningful" sustained discussion meant. Treating the thread as the unit of analysis, the contextual cues were utilized to explore the interrelationship among postings of IPs and non-IPs in ITs.

Coding the postings in the ITs

Except for the presence of IPs, what characteristics distinguished ITs from other threads? We were interested in what fostered the IPs. Postings did not occur in isolation but emerged as part of an ongoing dialogue, and by analyzing the attributes of the postings in an IT, we were able to reveal the distinctive qualities of an IT. For maximum effectiveness, we coded a sampling roughly 1/10 of the total, or 28 threads with 962 postings. The coding scheme was modified from Dillenbourg's (2003) work on the three concurrent processes involved in collaboration: the domain, the organization or coordination, and the social talks. The purpose of codifying these three categories was to explore the weighting of each category in the ITs.

Uncovering the interweaving of postings of three categories within ITs

The aforementioned 28 threads, with each posting codified, were then represented in a figure to show the interweaving of these ITs. The relationship between the effective discussion and the social talks was vividly revealed.

Based on this basic information, further analysis of the dynamics within threads followed, defining the profile of the threads qualitatively. Based on the data represented in Figure one, we blocked a few typical sections of the interweaving of postings distributed among these categories and illustrated them in a detailed manner. The representation of the juxtaposition of these sections is used to uncover the placement and context of effective discussion.

RESULTS

In this section, we will report the quantitative results of the context in which IP's appeared. By identifying the IPs in ITs, we were actually looking at the role of social talks in these ITs, and clarifying the interplay between effective discussion and social talks. We first give a profile of the important ITs, by paying attention to how these IPs are surrounded by the non-IPs and are supported and enabled by them. Then, using selected sections from ITs to illustrate how the online discussions were overwhelmed by the phenomenon of “on-task” postings going hand in hand with “off-task” postings, we reveal how learning actually occurs.

The surroundings of the IPs in their own ITs

From a total of 10490 postings, 2688 IPs were identified in 321 threads. 37% of them emerged in the Beginning part, 34% in the Middle part, and 28% in the Closing part. The IP frequency count in the Closing part differed significantly from that of the other two parts. It is surprising that IPs did not overwhelmingly emerge in the Closing part of ITs, that, on the contrary, they were developed more frequently in the earlier parts.

At first glance, the non-IPs in Closing parts of the ITs were full of tangential topics or housekeeping statements, but when the ITs are viewed as a whole, complete with the non-IPs, the contextual cues are seen to support IP development in a meaningful position. Here are two examples illustrating the context of an IT with no IPs in the Closing part and their connection to the rest of the non-IPs in the Closing part of the IT.

Table 1 the distribution of the position of IPs in two selected ITs

thread ID	# of postings	Life span (day)	The Beginning part			The Middle part			The Closing part			# of IP
Categories of the postings D = Domain C = Coordination S = Social			D	C	S	D	C	S	D	C	S	
A5_43	68	8	143 IP)	0	0	5(2 IP)	2	7(1 IP)	0	7	33	6
C6_10	22	5	1	2	4	2(2 IP)	1	4	0	2	6	2

Example one: the last 45 postings were non-IPs in an IT consisting of 68 postings. (See thread 1 in Figure 1)

There were 3 IPs (6th, 12th, 13th) in the Beginning part and 3 IPs 3 IPs (20th, 21th, 23th)in the Middle part of the IT. In the Beginning part, the group members focused on the variables to be chosen and how to represent the relationships between the variables. Upon trying different ways of showing the results, one team member accidentally discovered a new relationship between two variables. In the Middle part, they discussed the difference between radical moisture vs relative moisture and revised their representation. In the Closing part, they uploaded their artifacts and finished their tasks for the week. They felt relaxed and began to be curious about who was not online during these busy days and what school each other attended. One member observed the artifacts done by other teams and regretted not being as good as they were. Another team member comforted her…..

Huan: I discovered that someone has not shown up so far. We have six people together but only five left messages. One is still unknown.

Yeh: Who? I know. Its shu-shu. She showed up at the first week, and then gone.

Huan: What’s your plan for high school?

Yeh: Art program in Shin-Gu Girl’s school.

Huan: Good luck! You will be very busy if you attend that program because the annual exhibit will keep you work around the clock.

Huan: By the way, did you get a chance to look at the artifacts of the other teams? Team A-16 did an excellent job. I really envy about it. They are very good at a special software for presenting the artifacts. Ummmm….

Yeh: Don’t be frustrated. They have their advantages. We have ours too. Even though ours are not as good as them, we tried our best!

The group members engaged in serious discussion only on domain-related tasks, after which they simultaneously engaged in social talks. It seems that, after a stint of heavy-duty office work, they needed a “coffee break” for a while. If these postings had been examined and sorted in isolation and out of context, they would be interpreted as digression and reflective of a non-concentrating team. However, analyzing the extended thread consisting of 68 postings from a macro-view, the role of these social talks suddenly became apparent: the participants were relaxing after their task-related discussions. The thread did not conclude with serious task discussions, but, as in face-to-face interaction, people need to maintain shared regard and to structure possible future activity (Jucks, Raechter, & Tatar, 2003)

Example two: the last 13 postings were non-IPs in an IT consisting of 22 postings. (See thread 2 in Figure 1)

There were 2 IPs (8th & 9th) in the Middle part of the IT. After an exchange of information on individual experiences with fog, some discussion ensued about the reasons for previous absences, the division of labor, and who would volunteer to do which parts of the project. Others were concerned about the unavailability of networking capability some members were suffering due to technical problems.

Angela: I feel embarrassed that I will go out to have fun tomorrow. I will be back very late. So please do not wait for me. I will be online on Saturday for sure…..My computer isn't work very well. I don't know why.

Little grass: Anyone who is going to upload our artifacts please read the information on benchmark section 7 "how to hand in assignments." I bet everyone should read it too because maybe you have to do this next time.

Latte: Can we negotiate who is responsible for upload our assignments? …. If everybody is busy, maybe I can do it this week. ….By the way, does anyone know when Yeh is going to be back?

Latte: I thought Rita mentioned before somewhere he is having a summer camp soon. I bet we can expect his back soon. That's what I thought…..Don't worry too much. Angela, if you feel that something wrong with your computer, you can scan it. Mine is too. If we don't do something, it will be sent out for repairing right away.

Little grass: hello, Latte and Angela, make decision on who is going to upload the assignments…….. I don't know when Yeh will be back. But I believe it will be soon. Cheer up!

During that week, this group lost more than 3 members who left or were planning to leave for another summer camp. This situation bothered the remaining members a good deal. Although the remaining members made progress, they spent a lot of time discussing and figuring out the fluctuation in membership. They then announced anticipated absence days to let their partners know. It was because they cared that they didn't disappear silently. The forum is not a place reserved exclusively for the handing in of tasks; it's a place for them to live and to be together.

The distribution and the interweaving of varied categories of postings within ITs

962 postings from 28 threads were sorted into three categories: domain, organization or coordination, and social talks. 48% were in the domain category, with 22% in organization or coordination and 30% in the social talks. Using these coding results, the interweaving of different categories of postings within the 28 ITs are represented in Figure 1. In this figure, each line represents one IT, with black, shaded, and white representing the Domain, Coordination, and Social talks categories respectively. IPs are represented by bars of double height.

It seems clear that ITs are found with various combinations of the three post categories. The ratio of postings in the three categories was roughly 5:2:3. Few threads were composed of only domain-related postings, and task-related discussions tended to be mixed together with coordinated discussions and were frequently surrounded by social talks. What roles do coordination and social talks really play? We will take a few selections of ITs as an example.

Social talks as required greetings in the online world.

A thread may last from several hours to a few days. Each time group members logged in, they would say hello to their group colleagues, and would later say goodnight as well. (See thread 3 in Figure 1)

Yeh: Sorry, I have not dare to speak up for quite a long time. Since Grass encourages me a lot, I am eventually delurking. I fee sorry about that.

Grass: Hello, A-nei, are you online? Latte is online too. Angela~~~ Long time no see~~~~

Grass: What a pity! A-nei just got off a moment ago while you login.

While in the face-to-face environment we say "goodbye!" to mom when going to school, she would kiss us and say "Be careful on the road!"; and when returning home, we say "Mom, I am back" and mom would say "All right! There is a cake in the refrigerator." In contrast, in online discussion forums, one cannot tell who is coming because there is no noise (i.e. as there would be when someone enters a room) when somebody comes (logs in) or leaves (logs off). Therefore, whenever group members log in, they announce that fact, posting, for example, "Sorry, I had a good sleep and just woke up." Or "Because of ………., I finally am here." In short, Just as people say "Hello!" and "Bye!" in face-to-face daily life, when they meet and depart, group members in discussion forums express their greetings by leaving a written record of having arrived and departed.

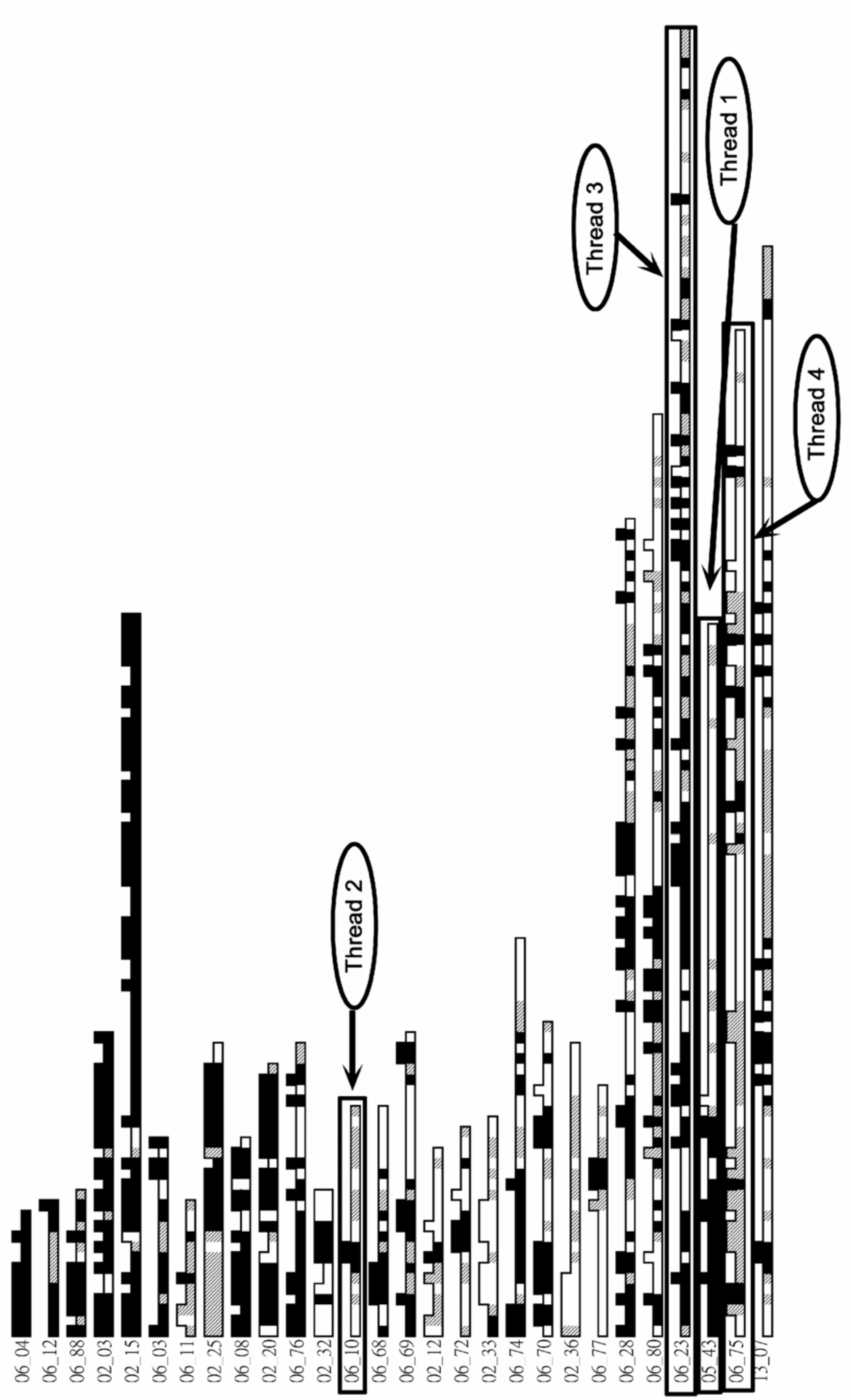

Figure 1 The interweaving of various postings in 28 threads

Social talks as the context in which the division of labor is negotiated

In an online group discussion forum, the learning activity does not take place in a serious and concise atmosphere. Instead, give-and-take collaboration quite often develops in an indirect way through social talks. In the following posting, for example, Latte mentions daily life in the real world a good deal, but mixes it together with an account of her expectations of group members and their mutual responsibility. (See thread 4 in Figure 1)

Latte: I really want to go to bed. Grass, I want to ask you one thing. Was the one you sent to me the second figure in case #8? I told you that I was planning to think about it for a while. Actually I was trying to figure out how to conduct that figure. I almost knew it except not knowing how to change the Y-axis all at a time. I was trying to log in last night, but I failed. I think it was probably because the University server's turned off. So I played the game instead, but I dare not to wakeup my mom. So I have to log off. Tomorrow I am going to conduct the second figure. But you must modify it. When you get home around 10pm, you will receive that figure, and of course we have to discuss how to conduct the third figure very soon…..)

Figure one reveals the genuineness of learning within online discourse. There is no clear demarcation between task and "non-task" contexts. The repertoire of these threads broadens our vision of online discussion. Threads easily and frequently switch in and out of on-task and non task contexts, focusing for a short while on social issues and then returning to the task at hand. (Kreijns, Kirschner, & Jochems, 2002). But the alternation between the black and white blocks in figure one and its significance to online learning is deserving of further exploration.

DISCUSSIONS

We began this paper by arguing that the examination of effective discussion was an interesting subject of study due to the ambiguous role that social talks play in effective discussion. In order to explore the substantive dimensions of group learning in online discourse, we first asked the question of how to identify effective discussion, not from the perspective of designers or researchers seeking an appearance of interaction (i.e., sustained, on-topic), but based upon concrete evidence provided by the learners themselves. Rather than identifying "effective discussion" by the learners individually, we proposed the concept of "Important Postings" (IPs) as perceived by members of the group themselves. A "Pick-n-Choose" was implemented to support learners in identifying the IPs from among the hundreds of postings. The "important threads (ITs)" were also identified.

Referring to the view put forth by Lave and Wenger's work on communities of practice (Lave & Wenger, 1991; Wenger, 1998), we found that learning in online discussion forums is also inseparable from the identity and life of the online community. Based on the findings of our study, we argue that a theory of learning that ignores these connections cannot account for when, how, or what people learn. Therefore, the findings are discussed based on the perspective of social theory of learning (Wenger, 1998).

From this perspective, learning is a kind of social participation. It is a process involving active participants in the practices of social communities and of constructing identities in relation to these communities. What we should be looking at in online discussion forums is not only the kind of action (i.e., postings), but also a form of belonging. The process of learning is the experience of meaning; the product of learning is a sense of meaningfulness and belonging.

However, many discussion forum research methodologies ignore the factor of an educational cue arising from a sense of belonging. Using ITs as the unit of analysis, we realized that identity is not all that abstract. It manifests itself in what learners say, the perspectives they adopt, and the way in which they react to certain statements. People's participation in a discussion reflects the way they look at the world, and therefore the trajectory that has led them where they are (as well as their sense of where they are going) (Wenger, personal communication, October 08, 2004).

Rediscovering the "social talks" in discussion forums——a picture of group identity

From the results of this study, we have gained a better understanding of the social nature of online discourse. But are these social talks really "off-task" or "off-topic"? In online discussion forums, participants discuss "soft" things more than task-related material because they care about each other. They announce their daily schedules because they have developed mutual accountability. They share feelings of loss when finding themselves to be the remaining members after the group has lost members because they have a sense of "our" group. What these social talks reveal is a picture of group identity. By examining the content of postings across each thread, the contextual environment of learning is uncovered. The cases discussed in this study indicate a kind of subtle atmosphere within which important discussions are generated. It is the social talks that make the group cohere. As Gunawardena (1995) suggested, once a positive affective relationship and sense of community have been established, enhanced task accomplishment may be achieved. This study empirically justifies the existence of social talks in effective discussion and identifies them as an inseparable part of effective discussion.

From this perspective, the significance of postings such as greetings, shared regard, introductions, or inquiries about the social life of fellow group members in the real world becomes clear: those interactions are not irrelevant to learning. Instead, these postings are meaningful in that they are negotiating meaning. Getting to know each other, finding communal interests, giving and receiving regards, and showing responsibility to the group are all a form of participatory identity. During the process of developing this sense of belonging, their joint enterprise is continually being negotiated. It is not the tasks but the sense of belonging that contributes to learning. Therefore, in ignoring the part social talks play, we lose the opportunity to uncover the substantive dimension, the identification and negotiability of learning in online discourses.

Social talks are not irrelevant to learning but are important to group cohesiveness prior to effective discussion. Improvising social talks among group members provides a deep common ground for important postings as well as for important threads to be generated.

Rediscovering effective discussion through social talks－－discussions embedded in social talks are the complete picture of effective learning

In contrast to the claim that the success of systems in CSCL environment may rest on the satisfaction of non-learning goals as latent variables (Jucks, Raechter, & Tatar, 2003), this study found that there are facets to effective participation in an online community. As community knowledge involves not only facts (i.e., What factors influence the rainfall of a typhoon in Fall in Taiwan?) and skills (i.e., How to represent the relationship among four factors in a figure?), but also a knowledge of social relations and practices (Greeno, Eckert, Stucky, Sachs, & Wenger, 1999).

By analyzing the context of "IPs" (Figure one) , we discover that an IP occurs in a thread containing numerous social talks and much procedural coordination in addition to " the on-topic" activities sought in the traditional perspective. The extended sequences of threads show the various distributions of postings in different categories during asynchronous interaction. In terms of the category of IPs, important postings are not limited to the "Domain" category only. In terms of the combination and development of ITs, important threads may be initiated by a posting in any of the categories, Domain, Social talks, or Coordination.

This study reveals that social talks are so omnipresent in the process of negotiating meaning that we hardly pay attention to their existence in the discussion forums. In particular, the postings sorted as Social Talks occur in the ITs at any point, and are of varying length. On the one hand, it is obvious that most social talks do not serve as distractions, continuing to the end of a thread to the exclusion of other material. On the other hand, even though social talks do tend to aggregate at the Closing part of the thread, they are found to be serving as after-meal talk in contrast to the earlier hard work.

The positions of IPs in threads were also found to contradict common assumptions about the process of knowledge co-construction. The fact that important postings are distributed roughly equally through most of the threads alters the impression that the accomplishments of decision-making or meaning negotiation will commonly terminate a discussion. Learning takes place when cognitive and social interactions naturally intertwine, as they do in activities (Scribner, 1984). Effective discussion and social talks are thus interrelated. Accordingly, from a community perspective, meaning is negotiated continually, and learning takes place not only through doing (domain-related), but also through becoming, belonging, and experiencing (Wenger, 1998).

CONCLUSIONS

The major implication of this study is the value of coordinating on-topic and off-topic perspectives on learning in discussion forum. We empirically justify that "social talks" is neither a necessarily non-productive, nor an analytically separable type of communicative action. With the scope of analysis in the context of entire discussions (threads), we are able to reveals the social nature of online discourse in an inquiry-based learning environment.

Most recent research in collaborative learning focuses on characterizing the patterns of effective or productive collaboration. Traditionally, those patterns that are sustained and focusing on on-topic issues are considered as effective learning. However, this study showed on- and off-task talks not only co-occur, but also interweave in supporting an effective discussion. Without social talks going hand in hand with on-topic discussion, group identity may not form substantially. In order to one step further propose more off-task talks lead to more on-task talks or engagement in the task, further research with ethnographic methodology is warranted.

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Animal Companions as Motivators for Teammates Helping Each Other Learn

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Abstract. This paper describes and discusses the design rationales of a system called My-Pet-Our-Pet that intends to realize an approach to using simulated animal companions to encourage students to help each other learn. A class of students is divided into several teams. Every student keeps her own *individual animal companion*, called My-Pet. An important component of animal companion is the student model of its master that supports self-reflection in different perspectives. Also, every team has a *team animal companion,* called Our-Pet, being kept by all the members of the team collaboratively. Our-Pet has a collective student model composed by all the student models of the team members. The design of Our-Pet help set a team goal through participating a competition game among Our-Pets of different teams, support collective reflections among team members, and shed light for the team how to help each other. We are currently conducting an experimental trail of the system in an elementary school where every student in the class has a Tablet PC.

Keywords: Learning companion, team animal companion, student model, active student model, open student model

BACKGROUND

With the development and advance in computer and information technology, computer supported collaborative learning (CSCL) environments bring more opportunities to foster communication and interactions in the social learning settings. Two kinds of approaches to realizing the CSCL environment: computers simulate intelligent agents to interact with learners, and computers provide smart tools or environments to foster social interactions among learners. A typical example of the former approach is the learning companion system in which the computer simulates two agents, a learning companion and a teacher, so that the user student can collaborate with the learning companion under the supervision of the teacher (Chan & Baskin, 1988, 1990). Chan (1996) also suggested that the student model can be used in different ways, other than hiding behind the student as an internal component inside the ITS. An example for this is the four animal companions that play different roles— collaborator, troublemaker, peer tutor, and tutee – based on the variations of student models interacting with learners to benefit learning (Chang et al.,1999). One way to use student model is to make it open or "inspectable" to the student for provoking self-reflection (Self, 1988; Kay, 1997; Bull, 1998; Bull, 2004) and later some researchers have been working on this direction. PHelpS system is an example that provides smart tools and environments to enhance social interactions among peer learners based on their student models (Greer el al., 1998).

Animal companions are simulated pets to be taken care by students who have to learn in order to earn the pet food. In our previous study of a simpler version of animal companion, My-Pet, (Chen et al., 2001, Chen et al., 2002; Chen et al., 2003) which was implemented in EduCities (Chan et al., 2001; Chang et al., 2003), we found that students demonstrated compassion and affection towards their pets, like Tamagochi (Webster, 1998; Pesce, 2000). For example, they expressed numerous feelings by emotional words on a discussion forum to show their care and concern about their pets. Because of these affective factors, students showed strong willingness of learning in the process of taking care of the pets (Chen et al., 2004). By the same reason, some students kept their My-Pets for a long time, about 5 percent of them for more than a year. After that study, in addition to improving My-Pet, we add Our-Pet in the system in order to promote positive interactions and helpful behaviors among teammates.

My-Pet

A student participates in learning activities to get resources such as foods and tools, so that the student can feed her My-Pet and play with My-Pet in many mini-games. My-Pet includes an important component, its master's student model, which is externally represented to the student by the attributes of My-Pet. Currently, the representation of this student model is a simple one. However, it includes cognitive, social, and emotional domains and there are a few attributes representing each domain. While the student is aware of her low academic performance on the cognitive domain by viewing the domain representation of her My-Pet, the student then participates more in learning activities. Similarly, when the student perceives her poor social performance, the student, to demonstrate her positive social behavior, may assist her teammates in learning to demonstrate her positive social behaviors. Figure 1 shows a student viewing the internal representation of multiple domains in My-Pet to reflect.

My-Pet plays three roles: a *motivator*, a *reflector*, and a *sustainer*. First, based on the human attachments to real pets (Melson, 2001), the strategy of learning by taking care of an animal companion triggers a student's emotional engagement and involvement in learning activities. The good will for My-Pet is the cause and learning is the effect. Although this initial motivation for learning is not for the purpose of learning itself, however, if the student later finds that the required learning is an intriguing and rewarding experience, this initial motivation may change qualitatively to motivation in learning itself. Second, self-reflection through viewing the domain representation of My-Pet, which is essentially the student model of the student herself in different domain, can help the student look at herself from different perspectives, and hence understand herself better or enhance her self-awareness. Third, pet keeping is a regular and long-term activity. With appropriate reinforcement, the system may be able to sustain some desired student behaviors and then to become a habit.

Our current version of the student model is a simple one but the framework offers flexibility for future extension and sophistication. The attributes of the cognitive domain include "what have learned", which is a record of what topics the student supposes to have learned, "degree of understanding" of concepts involved in a topic, "mastery level" of a topic, "overall performance", and so on. The attributes of emotional domain currently include "confidence" and "interest". Confidence is evaluated by the rate of successes in answering questions correctly or solving problems of a topic and that "interest" is determined by the frequency the student involved in learning activities of a topic after class or even if the student is not asked to do so. The attributes of social domain consist of "reminding" and "helping", which represent the student's collaborativeness. We use honor system, that is, the student reports to My-Pet how many times each time she "reminds" or "helps" her teammates to learn.

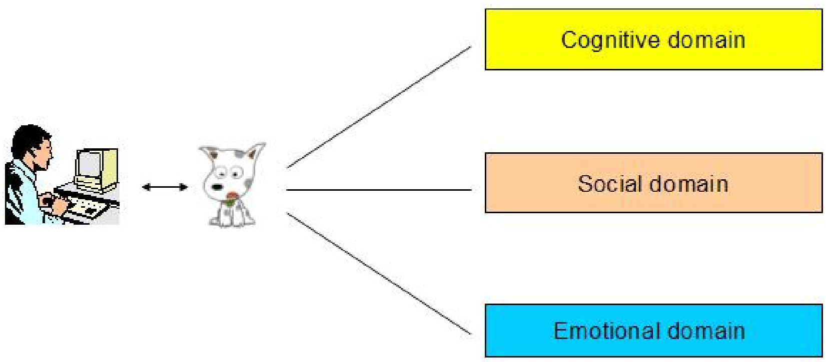

Figure 1. Student viewing My-Pet to reflect

Our-Pet

A class of students is divided into 4-children teams and each team takes care a *team animal companion*, called Our-Pet. As illustrated in Figure 2, a team's Our-Pet will interact with other teams' Our-Pets. An important component of Our-Pet that largely governs the behaviors of Our-Pet is a *collective student model*, with attribute values based on those in student models of all the team members. As this collective student model is "inspectable" by all members, it thus serves as a vehicle for promoting solidarity and collaborative behaviors of the team. In cognitive domain, there are four kinds of attribute values in that domain for each topic, namely, "minimum", "maximum", "average", and "variance" of all team members' attribute values of cognitive domain in the same topic. For example, "mastery level" of a certain topic is an attribute in the cognitive domain. Our-Pet's mastery value if adopts minimum, that means its mastery value is represented by the value of weakest team member. As all team members can view this value, other members will then naturally be urged to "help" or "remind" the weakest member to do more remedial work. If it adopts maximum, Our-Pet's mastery value will then be the strongest team member's value, and it then encourages the strongest member to do more for enrichment and strive for excellence, but then it will increase their "variance" value. With similar reasoning, "average" calls for more effort by all members and "variance" asks the stronger members to help the weaker members so that they can minimize their differences and hence the "variance". The mechanisms of emotional and social domains are similar to that of the cognitive domain.

Besides, all Our-Pets involve in a competition game as a motivator for members of a team to take actions to help each other learn. The rules of the game are designed so that winning and losing of a game depends on attribute values of two competing Our-Pets as well as luck. The competing game may use either attribute values in somewhat random way and thus the chance Our-Pet wins the game depends on all these attribute values and thus it demands efforts of all team members to improve all these attribute values. Each game has four rounds of competitions, and the game result is calculated by accumulating the results of four rounds. Each student stands for the team in one round by rotating three turntables to determine which domain, which attribute, and which kind of attribute value of Our-Pet to compete with the other team.

In sum, there are two roles of Our-Pet sub-system. The first is that the competing game will serve as a *motivator* for students to collaborate in order to win the game. The second is that the collective student model is an *indicator* that indicates how the teammates should help each other.

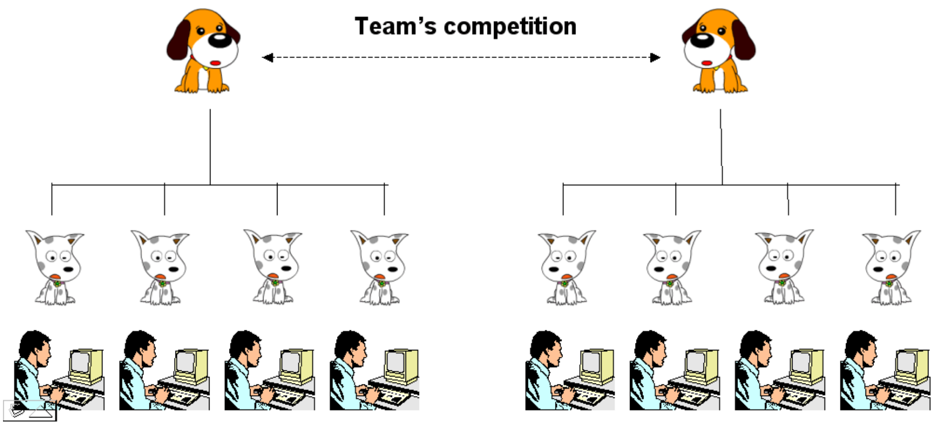

Figure 2. Intra-team collaboration for inter-team competition

IMPLEMENTATION

Figure 3 (a) shows that the My-Pet is eating food while being fed, and the student can inspect into domain attribute values of My-Pet. The subject domain of our current My-Pet-Our-Pet is idiomatic phrases for elementary students and can be easily transformed into other subject domains. For keeping My-Pet, a student has to earn a living for it – learning to get the resources such as foods and tools. In the current case, the student needs to participate in a series of activities for learning idiomatic phrase, including reading the historical story to understand the original meaning, identifying the key words, and practicing the applications of idiomatic phrases used in different contexts in our daily lives. If she can pass an assessment test, then she earns the required resources. Figure 3 (b) illustrates a four-children team where each team member has a My-Pet, taking care an Our-Pet. Every teammate can inspect the all other members' attribute values, in addition to Our-Pet's.

Different from our previous version of My-Pet used on Internet, My-Pet-Our-Pet, an extension of My-Pet, is used in the classroom where every student has a Tablet PC. My-Pet-Our-Pet now is being trial tested for future improvement of the system in an elementary classroom with 31 fifth-grade students. The students use the system fifteen minutes each time, and three times per week from November 2004 to January 2005. The results show that most students not only paid efforts in individual learning to improve the My-Pet's attributes, but also encouraged each other to study hard for Our-Pet's attributes. Some students also gave other teammaters hints on how to do well in reading, or helped others solve problems in learning idiomatic phrases. But the interaction and collaboration among teammates in learning activities still have many spaces to improve.

(a) Student inspects attribute values of My-Pet (b) Four-children team with Our-Pet

Figure 3. Snapshots of My-Pet-Our-Pet

SUMMARY

My-Pet-Our-Pet provides an ingenious way of adopting the metaphor of animal companion, underlying which is a student model, in a collaborative learning environment. My-Pet is essentially an active student model; yet, it is open to the student in an inspectable form. Harnessing affection and compassion brought by children's keeping pet hobbit, it provides a driving force for students to learn since their emotional engagement can direct to participation of some designed learning activities. Of course, we hope those learning activities can arouse their intrinsic motivation in the subject to learn itself. Also, representing student model in multiple domains offers the student a mirror to understand herself better about her own learning status from different perspectives. Furthermore, allowing students to view other team members' animal companions, they know what others have not learned, what have mastered, who need help, who can help, and so forth. Our-Pet, help establish the team goals that impel the teammates holding together to endeavor to realize their team goals. Besides it sheds light on directions how teammates help each other learn, hence positive social interactions among peers.

FUTURE WORK

As more and more researchers envision that one-on-one (1:1) educational computing, that is, every student has a computing device with wireless capability used as indispensable as a pencil, in a future not too long, will lead deep and far reaching changes in education (see www.g1on1.org), My-Pet-Our-Pet is being pilot tested in such a 1:1 classroom. In such an environment, our research team will develop a series of synchronous small group activities in class, including reciprocal tutoring, learning by asking questions, competitive learning games, and so forth. Also, we shall extend the content to some cardinal subject such as language and mathematics learning. As the subject matter and learning activities are getting more sophisticated, both individual and collective student models will be more complicate and thus these animal companion behavior will become more sophisticate. Thus My-Pet-Our-Pet is essentially a framework of incorporating all these efforts. Besides using in 1:1 classrooms, My-Pet-Our-Pet is also appropriate to be used via Internet after class to support individual or group learning or used in a large learning community such as EduCities where there are 1.3 million students using it (Chan et al., 2001; Chang et al., 2003)

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MatrixDesks: Interactive Computing Desks toward One-on-Two Educational Computing Environments

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Abstract. The era of 1:1 educational computing environment where each student has one mobile computing device is not far away. When such technology designed for individuals is applied to group learning, several student grouping problems could be encountered. In this paper, three issues are identified to illustrate the vision of the 1:2 educational computing environments. In a 1:2 classroom, besides the mobile devices, students also have their own computing desks, i.e. MatrixDesks, to solve the potential student grouping problems. By putting MatrixDesks together, a small group can form a shared working space with the combined desktops immediately and they can use their own digital pens as the input devices to work on and talk over it. Meanwhile, the students use their mobile devices to handle the related individual tasks. MatrixDesks is a coordination of applying the mobile computing and invisible computing to collaborative learning, which will lead to the accomplishment of 1:2 educational computing environments.

Keywords: student grouping, interactive computing desks, ubiquitous computing, invisible computing, 1:1 educational computing, 1:2 educational computing

BACKGROUND

Computing Desks

A classroom desk provides a working space for learning in the classroom. Students are used to have their own desks in class, and they are familiar with the interaction on the desk, such as reading, writing, painting, talking over the desk, sharing objects on the desk, etc. In the field of human interface interactions, there are several systems using the metaphor of desks, such as DigitalDesk (Wellner, 1993), meatDESK (Ishii & Ullmer, 1997; Ullmer & Ishii, 1997), Sensetable (Patten et al., 2001), InteracTable (Streitz et al., 1999), ConnecTable (Tandler et al, 2001) etc. Ishii and Ullmer (1997) also argue that the graphical user interface (GUI) approach falls short in embracing the rich interface modalities between people and the physical environments, and the desktop metaphor should be pushed back into the real world.

One-on-Two educational Computing

Many researchers have envisioned in a future not too far, a personal computing device for every student in a classroom will be as indispensable as a pencil. These devices could be products evolved from what we commonly see today like notebook, tablet PC, personal digital assistant (PDA), cellular phone, electronic dictionary, visual graphical calculator, gameboy, and so forth. This vision of 1 student 1 computing device classroom is termed as one-on-one (1:1) educational computing environment (www.G1On1.org).

Now, assuming 1:1 educational computing is already practicing in significant percentages of classrooms in the world, and given that the prices of large panel displays are dropping rapidly, *1:2 educational computing*, that is, 1 student 2 computing devices, will bound to happen. We envision one possible 1:2 classroom scenario is that every student will have a personal handy and light device that the student brings along with her everywhere, and in the classroom, her own desk is also a computer, that is, the desktop of her desk is a large computer screen. Such computer desks, which we call MatrixDesks, can facilitate nicely many small group learning activities in a classroom.

THREE STUDENT GROUPING PROBLEMS

Scott et al. (2003) found that sharing a physical display positively influenced the students' collaboration, rather than separate displays (whether in the same room or not). In the shared workspace, it is easy for students to reach a mutual understanding and to collaborate with each other. However, in a 1:1 classroom, it is not easy to construct shared workspaces, because students may bring their personal computing devices which could be different sizes or types. As one may imagine, in a classroom equipped with several computing desks, small groups of students will stand or sit around the desk with their eyes looking at their desks while talking with their neighboring students. Since one student will have her own computing desk in the classroom, the best way is that all students will put their own desks together to form a large desk so that they can sit around the large desk focusing their attention on the desktop, that is to say, the large computer screen composed of individual desktop screen of a computing desk. This student grouping problem we termed as *sharing screen problem*.

Since there could be plenty different small group activities with various ways of grouping students, combining desks to construct larger working spaces is a natural and reasonable thought for a small group of students. Now, their desks, suppose they can be moved easily around in the classroom, are arranged in different configuration for supporting these activities. For example, in Jigsaw collaboration, at first students split into several focus groups, which focus on different aspects of a common topic, and then they return to their home group to share their "expertise" learned from focus groups to produce a presentation about the topic. When students come back to their home group, their desks should change the grouping automatically. And when a teacher wants to conduct a group learning activity, he has to consider not only how to group the students but also how to make their desks understand the grouping configurations. There are several ways of grouping students with their devices. Typically, teachers have to make a list manually to tell the desks which ones are grouped together. However, this is a time consuming work for teachers, especially when some learning activities need to group students again. To solve this problem, a computing desk should be "aware" which desk is belonged to whom and which desk is currently attached to it and on which side. This is another student grouping problem and we term it is the *desk configuration problem*.

On the other hand, pen-based interfaces are one of the natural input devices for students on the computing desks. Generally speaking, such input devices are designed for a single user and dedicated to one computing desk only. When several computing desks are grouped, the students likely use their digital pens not only on their own desks but also on the entire shared workspace. In other words, the computing desks should have the capability to distinguish the group members' pens without ambiguity. In educational applications, it is crucial to track each student's actions. Such problem is termed as *input identification problem*.

This paper focuses on these three student grouping problems in 1:2 classrooms and intends to discuss possible solution for them. Actually, student grouping is a fundamental issue of collaborative learning, not only for 1:2 classrooms, but for 1:1 classrooms too. In the following sections, after discussion of related works, we present the design of MatrixDesks to support student grouping with tablet PCs or notebooks.

RELATED WORKS

Our original project of using tablet PCs in the classroom is called Digital Classroom Environment (DCE). Under the environment, there are several wireless access points put at different place in the classroom, and also a common display for projecting the screen of the teacher's tablet PC or notebook. Each student has a wireless-enabled tablet PC on which the student can make annotations on their content. DCE also provides both teachers and students to manage devices including broadcasting the materials, sharing annotations, etc. The Puzzle View (Deng et al., 2004) is a prototype that constructs a group display by combining several screens of tablet PCs (Figure 1). It provides shared working spaces among several computing devices and was designed for enhancing group interaction experience. However, it is noticed that Puzzle View is not facile for teachers or students to change grouping immediately. Furthermore, students also have to figure out the proper order of screens when they are grouped. The Puzzle View provides not only a solution to the *sharing screen problem* but a foothold to explore the other problems.

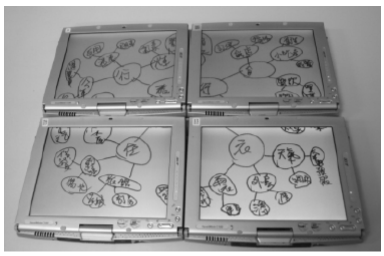
Figure 1: Puzzle View

For the purpose of building a meeting room, several roomware® (Streitz et al., 2001) components are developed in the first generation of i-LAND project, such as DynaWall, InteracTable (Streitz et al., 1999). The InteracTable allows a single user at a time using the pens or his finger for gesture-based interaction with virtual objects, while the DynaWall integrates tightly three interactive touch screens into a wall for a larger presentation area or parallel presentation areas. To enhance the fluidity of the interaction, ConnecTables (Tandler et al., 2001) are designed to dynamically form a homogenous display area. When two ConnecTables are moved close to each other, the workspaces are connected so that their users can work individually in parallel and exchange information. ConnecTable solves the *sharing screen problem* and, to some extent, the *desk configuration problem*.

SOLUTIONS OF THE STUDENT GROUPING PROBLEMS BY MATRIXDESKS

The design of MatrixDesks is to solve the *sharing screen problem*, *desk configuration problem*, and *input identification problem* so that students' experience can be improved in group learning activities. MatrixDesks have wheels to assist students to move their desks easily. Each MatrixDesk is designed for one student with the desktop being a sensing display, which is a large screen of an embedded computer (Figure 2). For writing and painting on the sensing display, every student has a digital pen with its unique electromagnetic identification which can be sensed by the sensing display. Such technique is used to solve the *input identification problem*.

Let us assume a MatrixDesk is a square desk. The *desk configuration problem* can be simplified by calling a function of MatrixDesk for detecting the neighboring desks automatically. This detecting function take the value of an electronic identification (such as RFID, Radio Frequency Identification) labeled on each side of the desk as an input and activate a sensor when the two desks are attached (Figure 3). Similarly, when another MatrixDesk is put together, they can detect each other and tell the computers with whom they are put together and in what shape, such as rectangle, square, or other irregular shapes such as L, T, or U shape. Figure 5 shows an example of the desk configuration if the desktop is a square.

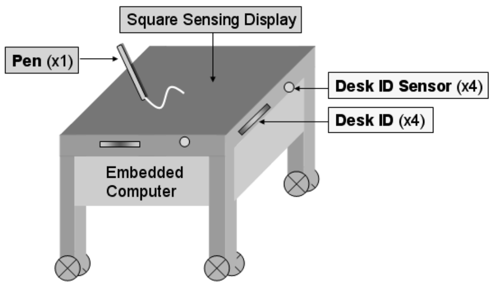

Figure 2: The sketch of a MatrixDesk

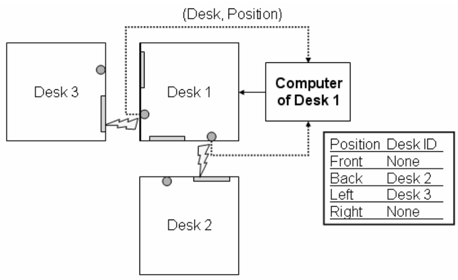

Figure 3: The neighbors detecting function

Figure 4 shows the system architecture of MatrixDesks, which are client/server architecture. MatrixDesks are equipped with wireless communication capabilities so that these desks can transmit data through wireless networks to the server which is either a centralized class server or one of the desks. **Neighbors detecting module** receives the signals of the four desk identification sensors. After detecting the neighboring desks, the module sends the data of the identifications and orientations of neighbor desks to the server. According to the data, **shared workspace analyzer** of the server groups the corresponding desk identifications, and analyzes the layout of shared workspace for the best viewing experience. Then **display generator** dispatches the workspaces to the respective desks, which are to present the workspaces on their screens. The whole process is used to solve the *sharing screen problem*.

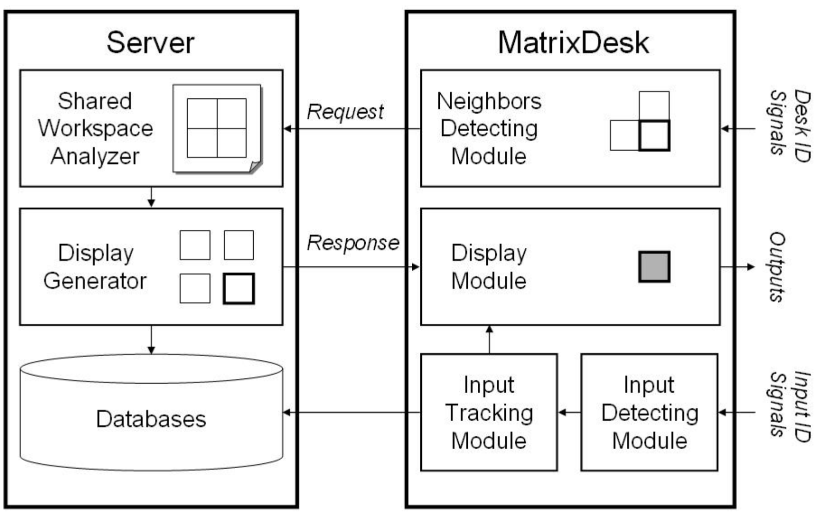

Figure 4: system architecture

Input detecting module receives the identification and position of the digital pen, and then these data are transferred to **input tracking module** which can identify and track which pen is sensed on the desktop. In this version, MatrixDesks are simply designed to allow students writing, drawing, painting and making annotations, so the students' handwriting can be output directly without being processed through the server. In other cases, such as exchanging or connecting virtual objects, the module needs to send the data to the server, so that the actions can be performed correctly. Finally, **display module** presents the adequate workspace as the background and the handwriting as the foreground on the screen. At the same time, both data are logged in databases for future analysis.

To construct a shared workspace, the server allocates a working space and, according to the desk configuration, maintains the relations between desks. When students change the configuration, computers only need to change these relations rather than to create a new shared display again. After putting several MatrixDesks together, students can sit or stand around the desks to share the workspaces with their digital pens. Figure 6 shows several possible ways to use MatrixDesks when two desks are attached, including facing each other or side by side, which depend on the learning activities and materials. For example, if the students try to compare two diagrams shown on MatrixDesks separately, they can share the workspace side by side.

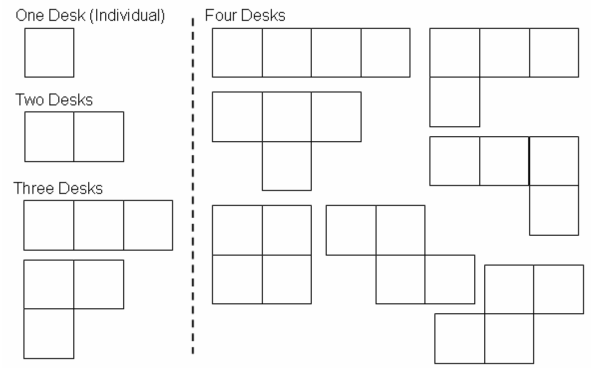

Figure 5: Possible combinations of MatrixDesks

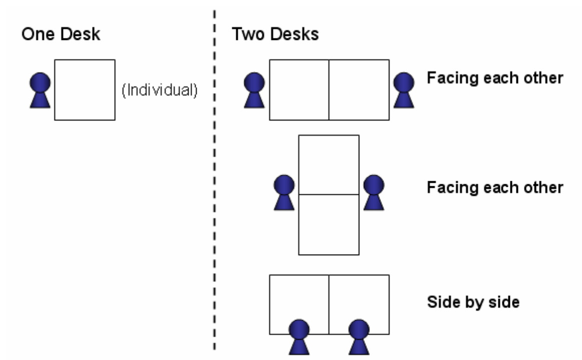

Figure 6: Possible ways of sharing working spaces

When comparing to students using the screens of MatrixDesks for individual works, how frequent a small group of students would need such a large shared screen in a class is not known. Therefore, it is important to be able to switch between individual work spaces and shared work space. Note that when students work individually, they can still exchange data or communicate through verbal or online chatting. Also, we do not plan to ask computer manufacturers to produce machines with screens as complete desktops. Instead, we embed tablet computers with their screens large enough into usual desktops. RFID is used to attach to the desks to identify the mutual locations and orientations of the sides of the simulated MatrixDesks.

Another design challenge is how to support learning activities with the mobile devices and the computing desks in 1:2 classroom scenarios. Remember that 1:2 classroom is an enrichment of 1:1 classroom where every student has already had her own device of which we anticipate that its size will be about that of a handheld or an electronic English dictionary. In 1:2 classroom scenarios, a learning activity ought to be divided into two parts, the individual tasks and group tasks. The individual tasks are performed on the mobile devices, while the group tasks are supposed to be done on the computing desks. For example, when students work as groups with the shared workspace, their individually owned devices may serve as interactive books for reading and taking notes which can be transferred to the shared workspace if needed. When students work individually, these mobile devices will become communication tools with their desks.

SUMMARY AND FUTURE WORKS

In a classroom of future, besides having a personally owned portable small-size screen handheld, every student is provided with a personal computing desk. Furthermore, while researchers talk about wireless and mobile technologies in CSCL today, the genuine mobile learning is merely about the use of the portable computing device that the student brings along with her all the time, at home, at school, as well as outside classroom. But at home and in classroom, she may largely works on a computing desk, one at home and one in every classroom she goes in, complemented with her portable computing device. This is the most feasible and practical scenario we envision in the era of ubiquitous computing (Weiser, 1998), that is, seamless computing, or simply everyday life computing. In a word, the 1:2 educational computing links the research areas of mobile computing (Gay et al., 2001) and invisible computing (Norman, 1998) applied to teaching and learning.

If desks are regarded as bridges between individual and group learning in classrooms, then MatrixDesks provide personal computing working spaces as well as a cooperative working space for a small group and are able to switch from individual to group environments and vice versa at ease. This project is currently a work in progress and our next step of MatrixDesks is to finish the implementation of our prototype. At present, MatrixDesks is only a frame in which learning activities and materials should and will be placed. Hence, there will be further experiments and investigations that can support the improvements of our design. For example, we would like to know how the students interact with the desks, including the positions of students, the handwriting they make, the ways to share the displays, to talk over the desks, to walk around the desks, and to move the desks, and so forth. Furthermore, this paper also raises a few design issues, in particular, three student grouping problems, of such a future 1:2 classroom to initiate the exploration of the related issues. The researches of collaborative learning with mobile devices and with invisible computers are somehow divergent and need to be accommodated. If we continue studying the 1:2 educational computing environments, more CSCL issues hidden between the two researches will be discovered in the future.

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Problem-Based Learning Online: Multiple Perspectives on Collaborative Knowledge Construction

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Abstract. Online problem-based learning (PBL) environments afford many opportunities to engage in collaborative knowledge construction. Activity theory is a suitable framework to study such environments and the processes learners go through when using these environments. Two complementary perspectives are blended in this paper in an attempt to create a comprehensive picture of learning using an online PBL system. One perspective is the detailed analysis of tool use and discourse students and facilitator engage in. The second perspective is facilitator reflections about the evolution of the group's collaborative practices and norms.

Keywords: Problem-based learning, online learning, collaboration

INTRODUCTION

Problem-based learning (PBL) is inherently collaborative (Barrows, 2000; Hmelo-Silver, 2004). In PBL, students work in small groups with the guidance of a facilitator learning through solving problems and reflecting on their experience. Moving PBL online can provide scaffolding to further support collaborative knowledge construction. Collaboration allows learners to share ideas and develop new, authentic solutions to problems they are trying to solve, and, while doing so, acquire useful knowledge of theories and concepts (Hmelo-Silver, 2004; Palincsar & Herrenkohl, 1999), In PBL, students collaborate on complex problems, thereby distributing the cognitive load among group members as well as taking advantage of the distributed expertise within the group (Pea, 1993). Exchanging information is an important part of learning together as knowledge is constructed socially through joint efforts towards common objectives. As some would argue, the very essence of collaboration is the construction of shared meaning (Roschelle, 1996). From this sociocultural perspective, as learners participate in activities, they internalize what they have learned from working together (Palincsar & Herrenkohl, 1999; Vygotsky, 1978).

This view of learning also accounts for the important role of tools and discourse in mediating learning. In particular, activity theory serves as a framework for understanding how learning occurs in complex environments (Engeström & Miettinen, 1999). Each activity is composed of a subject, an object, mediating artifacts, community and division of labor and rules. Two basic processes are found in any activity – internalization, a process of shifting the material from the social plane to an individual and, externalization, a process of joint construction of an understanding of an activity, which is characterized by a movement of material from a person to the social environment (Valsiner, 1997; Engeström & Miettinen, 1999). These processes are complementary and intertwined, and help move the knowledge between the individual and one's social environment. In our work, we have moved PBL to an online eSTEP system that provides a number of tools to support individuals and groups as they engage in instructional redesign activities (Derry, in press). In addition, a facilitator works with the group to help guide their learning process. One of our goals of this paper is to understand how the online tools and facilitation mediate these transformations as students engage in collaborative knowledge construction. Because learning in this environment is multifaceted, we take the view that multiple methodologies are needed.

In this paper, we examine two perspectives on collaborative knowledge construction as preservice teachers engage in an online problem-based learning activity. One perspective is a detailed analysis of online collaborative learning through chronologically-oriented representations of discourse and tool-related activity (CORDTRA), which allows us to look in detail at both collaborative discourse and use of various on-line tools to mediate this process (Hmelo-Silver & Chernobilsky, 2004). The second perspective includes the reflections of a facilitator who tries to understand the role of facilitation in this online problem-based learning environment. In introducing the two perspectives we are blending the more fine-grained mixed methods analysis (Hmelo-Silver, 2003) with the traditional, ethnographic approach to studying activity systems (e.g. Cole & Engestrom, 1993).

eSTEP SYSTEM AND ACTIVITY STRUCTURE

eSTEP system is an on-line problem-based learning environment (Derry, in press). The goal of this system is to provide preservice teachers with an opportunity to engage with learning sciences concepts while using video cases as contexts in collaborative lesson re-design. The system consists of three components that are intended to mediate student learning. One component is the online learning sciences hypertext, the Knowledge Web (KW). The second component is a library of video cases that present examples of classroom instruction. These video cases serve as the basis for instruction as they present opportunities for discussion and improvement of instruction depicted in the cases. The video cases are intertwined with the KW. Finally, there is PBL online student module. It is a collection of tools that scaffold students' online individual and group work following a PBL format (Hmelo-Silver, 2004). Some of the tools that are presented in this environment include a personal notebook where students record their initial observations, a threaded discussion board, where students share their research and analysis of the video cases, and a white board where the students post their proposed solutions for the lesson redesign. eSTEP is a complex system because learning occurs during a combination of nine intermingled face-to-face and online steps. Additional details about the system can be found in Derry, et al. (this volume) and Hmelo-Silver, et al. (this volume).

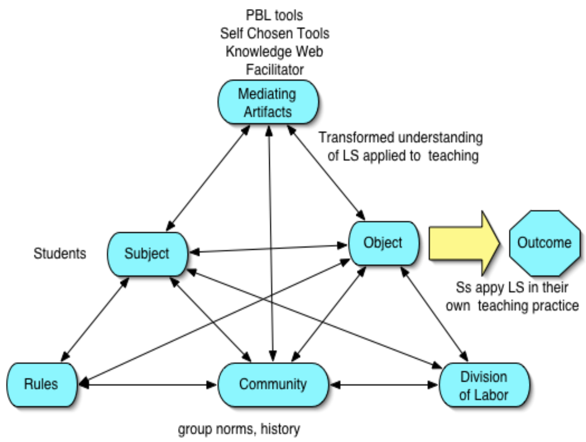

Figure 1: STEP activity system

During eSTEP activities, students interact and engage with various parts of the activity system as depicted in Figure 1. The objective of the learning activity is to analyze a videocase using learning sciences concepts and to subsequently apply those concepts to their own instructional design. In the course of this study, students worked on three online problems. In the first of these problems, the students viewed a video of an inquiry-oriented classroom in which children were engaged in design activities to learn science (Kolodner et al., 2003). In this problem, the students were asked to design an approach to assessment. In the second problem, the students watched two video cases. One showed a traditional physics teacher who used lectures and demonstrations. The other, contrasting video case, showed a constructivist instructional approach. The students were asked to help the first teacher adapt some of the techniques the second teacher used in order to improve the lesson on static electricity. The third problem showed a video of a foreign language teacher who wanted to redesign her lesson to meet new foreign language teaching standards.

PARTICIPANTS

The participants included a group of five students and a facilitator who worked together in three online PBL activities. The facilitator had two roles: to assist the students in the PBL process by guiding them through the steps of the activity through metacognitive guidance (Hmelo-Silver, 2004), and by answering their questions and guiding them in using the eSTEP tools effectively. The group was part of a larger Educational Psychology class in a large Northeastern University. This group was among the top two groups in the class performance-wise. We chose this group and not the other because the first group exhibited consistent performance throughout the semester. This group, on the contrary, revealed a dramatic evolution in group dynamics, involvement in the task, and productivity in face-to-face and online discussions and development of redesigns across the three online problems they participated in. Since our primary interest was in learning how tools mediate activity and learning, we felt that this particular group would be better suited for this purpose.

CODING AND ANALYSIS OF ACTIVITY

The discourse of the group was coded for content, collaboration, questioning, complexity, justification, and monitoring. These categories were chosen because they serve as indicators of cognitive engagement (Hmelo-Silver, 2003). Each category was further broken into subcategories as shown in the examples presented in Table 1. In order to address the issues of complexity, the Bereiter and Scardamalia (1987) scale was adapted. The adapted scale included three categories: telling, elaborated telling and transforming (Chernobilsky, daCosta & Hmelo-Silver, 2004). An utterance was coded as telling when students talked about the concepts without elaboration or clear connection to the problem. Utterances coded as elaborated telling were those where the students provided more conceptual details but where the connections to the case were not evident. Transforming utterances were those where students provided deep elaborations of the concepts together with coherent theoretical interpretations and a clear connection to the problem.

Table 1. Examples of coding categories.

	Category	Example
Content	Task-related utterances	I recommend that you spend a bit more time on discussing EACH proposal and then vote let's say late afternoon on Tuesday.
	Tool-related utterances	Frank and I decided instant messenger may be useful for discussing comprised info and ideas.
	Concept-related utterances	Elaborative rehearsal better equips the student with the information he is rehearsing because it becomes more accessible in his long term memory he has found ways to relate it to other instances and in his own words and he can help his peers understand it on a more simple level.
	Personal talk	Hey, I just wanted to let everyone know that I will might be a little late logging in on Monday morning. I will be in Connecticut until early Monday morning.
Collaboration	New Ideas	Peer assessment done by each student in each group on their group members.
	Modifications	I don't think its necessary to peer evaluate within the groups. We might try to give roles out within the group to make sure that each student has a part in the experiment and is working and not slacking off.
	Agreement	I like Mary's proposal for a hypothesis sheet…
	Disagreement	I don't believe peer assessment should be a factor in the student's grade but it could be done as feedback for both students and teachers to use.
	Summaries	What we have so far: Jack – teacher beliefs, Beth – hands on learning, Ellen - prior knowledge use, Carol – cognitive flexibility theory, Sylvia – collaborative learning
	Acknowledgment	I like Mary's proposal for a hypothesis sheet.
Questions	Informational questions	Should we meet before class at 9:15 so we can go over and refine what we have done?
	Explanatory/ elaborative questions	What do you mean by self-regulated learning?
	Metacognitive questions	What do others of you think?
Complexity	Telling	direct instruction: method of instruction for mastery of basic skills, concepts, strategies, facts, and information. This instruction is done piece by piece rather than all together. …
	Elaborated telling	Games and activities that students are familiar with can help teach specific facts about a country its culture, and its language. … I thought Monopoly would be a good game to use. As long as it was carefully coded as to appropriate linguistic level and maturity level suggested for students.
	Transforming	This idea supports our objective of "Transfer knowledge of static electricity to everyday examples" And so both motivation and transfer can be achieved through Authentic Instruction, two characteristics of which are Students' work has value beyond the school setting. Lessons become more authentic as the connection to the real world is increased. … Thus, one (authentic) activity would be a field experience (trip) to a lab, power plant, etc., which would should real

		world use and is social.
Justifications	Personal experience/ belief	I think a good assessment is to have each student do a mini science project based on static electricity, which I think would encourage students to think more and to not just concentrate on a grade.
	Grounded beliefs (clearly evidence based)	According to Sociocultural theory, "to capture a student's motivation, the culture of school must find a way to be valuable, relevant, interesting, and challenging in the eyes of a child. This may mean engaging the students in authentic activities of the larger society. It also means challenging them with tasks that are meaningful to the larger culture and are relevant to their lives outside of the school environment." …
Monitoring	Individual monitoring	I have made a summary about the stuff I got from the knowledge web that i posted as well as my research and printed it out so we can attach it to our sticky paper on Thursday.
	Group monitoring	Ok, so I think we need to revise or come to a concensus about how we want to word our final proposals.
	Self-directed learning	I will research metacognition. I still need to look up the concept of "self-directed learning"
	Planning (other than SDL)	Let's meet on Monday after class to talk about our gallery walk.

During the activity, students used several eSTEP tools, including PBL-online, KW and research library, video cases, whiteboards and discussion boards, online help, personal notebooks and lesson plans. The whiteboard served as the editable solution space, where students could post and edit their solution proposals during and after discussions.

To make sense of our data, we used CORDTRA diagrams, a methodology adapted from Luckin (2003). CORDTRA is a tool that allows us to examine relationships between the various parts of an activity system, particularly between the students, the discourse they engage in while collaborating, the tools they are using to solve the problem, and the artifacts they produce. An advantage of CORDTRA diagrams is that they can include as many or as few coding categories and tools as needed (Chernobilsky, Hmelo-Silver & DelMarcelle, 2003). Here, we include the various tools that the students used, the particular speakers, and the coded utterances.

To understand the CORDTRA diagrams (Figures 2 – 4) it is important to know that the data are arranged in chronological order. At the bottom of each diagram, there is a running count of lines of codes. Each code is either a tool that a student used or an utterance. For example, in Problem 1, the lines from zero to 200 are showing that the students in the group are mainly involved with the PBL online student module. They are also watching the video and looking into KW. There is some use of "Lesson Plans" tool as well. The tools, discourse categories and speakers are listed on the right of the diagram next to a corresponding string of codes. On the bottom of each diagram the arrows indicate when a certain step was begun by one of the group members. Although we marked the beginnings of each step, these are not the absolute ends of the prior steps – students are free to move between the step they are currently working on and the previous steps of the activity. For example, in problem 1 some students are still visiting steps 1 and 2 as late as line 883.

RESULTS

We present our results in two parts. First, we present the main results of our coding through CORDTRA diagrams that show how the group's pattern of discourse and tool use changed as they worked on the three problems. Second, we present the reflections of the facilitator based on her course journals.

CORDTRA

The CORDTRA diagrams are presented in Figures 2 through 4. Our analysis demonstrated that the group had a very different pattern of interaction from problem to problem. In Problem 1 the group showed limited collaboration (see Figure 2). The facilitator and one student (Jahnvi) were most active during this problem. One student did not participate at all. The participating four students had at least 3 utterances each. However, the quality of their discourse was low. For example, CORDTRA diagram shows that 14 questions were asked during Problem 1. Ten of these questions were explanation questions, with eight out of ten asked by the facilitator. There were very few new ideas (eight) and even fewer modifications (five). Looking at the discourse as depicted by CORDTRA, we see that students do not have any agreements or disagreements during the discussions, and throughout working on Problem 1, gave each other only three acknowledgements. This pattern of interaction suggests that although all students were online, they did not collaborate in solving the problem, but rather worked in parallel. This finding is supported by the fact that very few explanations and justifications (i.e., personal or grounded beliefs) were given during Problem 1.

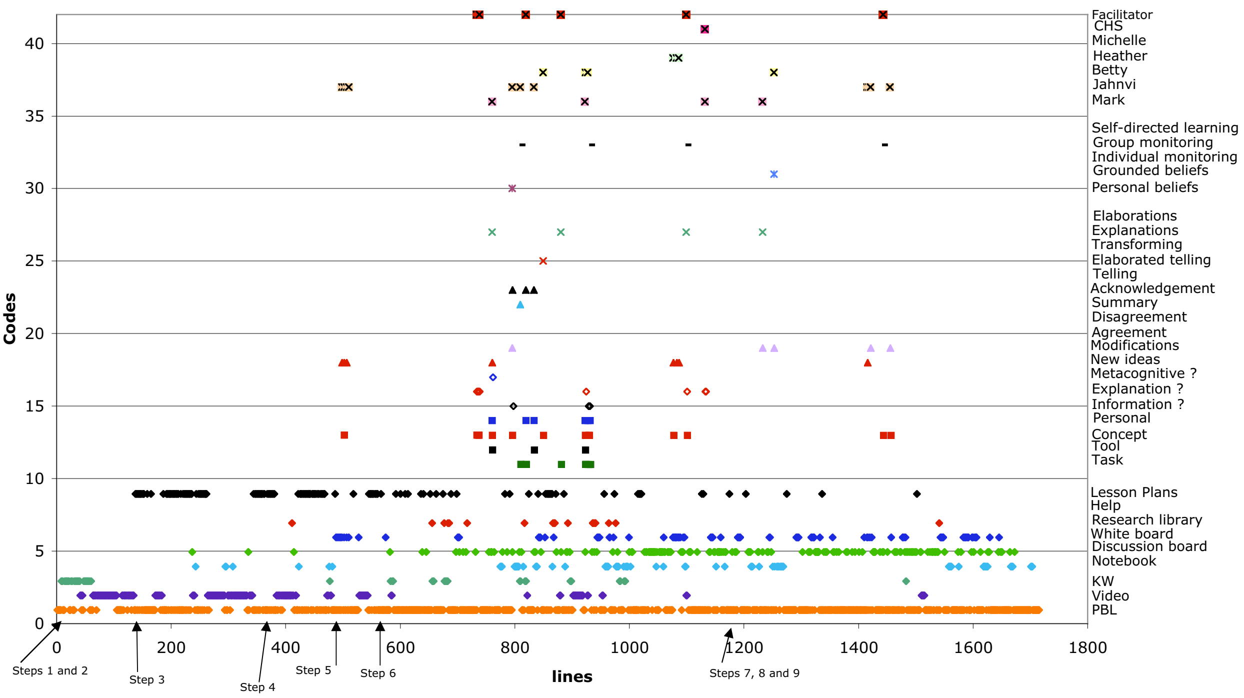

Figure 2: Problem 1 CORDTRA

The pattern of tool use in Problem 1 is also of interest. The most frequently used tools were the discussion and white board. However, at the same time, there was little discussed. This suggests that although students went on to see what was happening in the common tools area, they preferred to watch, not participate. It is interesting to note that the KW was rarely consulted. The students seemed to supplement the use of KW with the use of research library, another eSTEP tool that provides various references and links to the information outside of KW and eSTEP. Students spent a lot of time viewing the video prior to discussion and continued to use it during and to some extent even after the discussion.

In Problem 2, the pattern of tool use changed (Figure 3). Students viewed the video intensively at the beginning of Problem 2, just like they did in Problem 1. However, once the discussion started, the students did not use the video until the end of the problem. The use of the KW was also different. While it was very dispersed in Problem 1, in Problem 2, students used the KW specifically when working on steps 4 and 5, which are the research steps. At the same time, they were talking and discussing some concepts. This indicates that in Problem 2 there is a beginning of a reciprocal relation between the use of tools and discourse. The pattern of interaction and the quality of the discourse was also drastically different in Problem 2 as compared to Problem 1. Everyone actively participated – all students and the facilitator asked a lot of questions. Students brought in new ideas, and modified these ideas extensively, initially on the discussion board, and later on the group whiteboard. There were still no disagreements, but students did acknowledge each other much more than in the previous problem and explicitly agreed about what they were discussing. While students worked on Problem 2, four summaries were posted, three by a single student. We see the use of summaries as an important sign of an emergent successful collaboration. It appears that summaries help students see what they have achieved and assist them in setting further group goals that otherwise maybe difficult for the group to negotiate. In fact, CORDTRA shows that a lot of monitoring is going on, especially group monitoring by both the facilitator and the group members. Students also provided a greater number of justifications, although most of them were not evidence-based.

The pattern of interaction again changed in Problem 3 (see Figure 4). This was the last problem of the semester and students were simultaneously preparing for the “end of the semester” mastery test. CORDTRA thus reveals that the use of the tools continued long after the problem was finished (approximately line 1300). Although students continued to visit the discussion board at the end of the problem, there was nothing posted. This suggests that students continued using the information that had been posted on the discussion board, along with other tools, as a resource in preparation for the mastery test. CORDTRA also shows that the pattern of KW and video use was different. This time students did not use video while talking. Instead the use of the KW increased. This suggests that students better understood when and why they were to use KW in order to improve the quality of their arguments. Again, the facilitator and students in the group were asking a lot of questions, and the students brought in a lot of new ideas, modifications and explanations about their points of

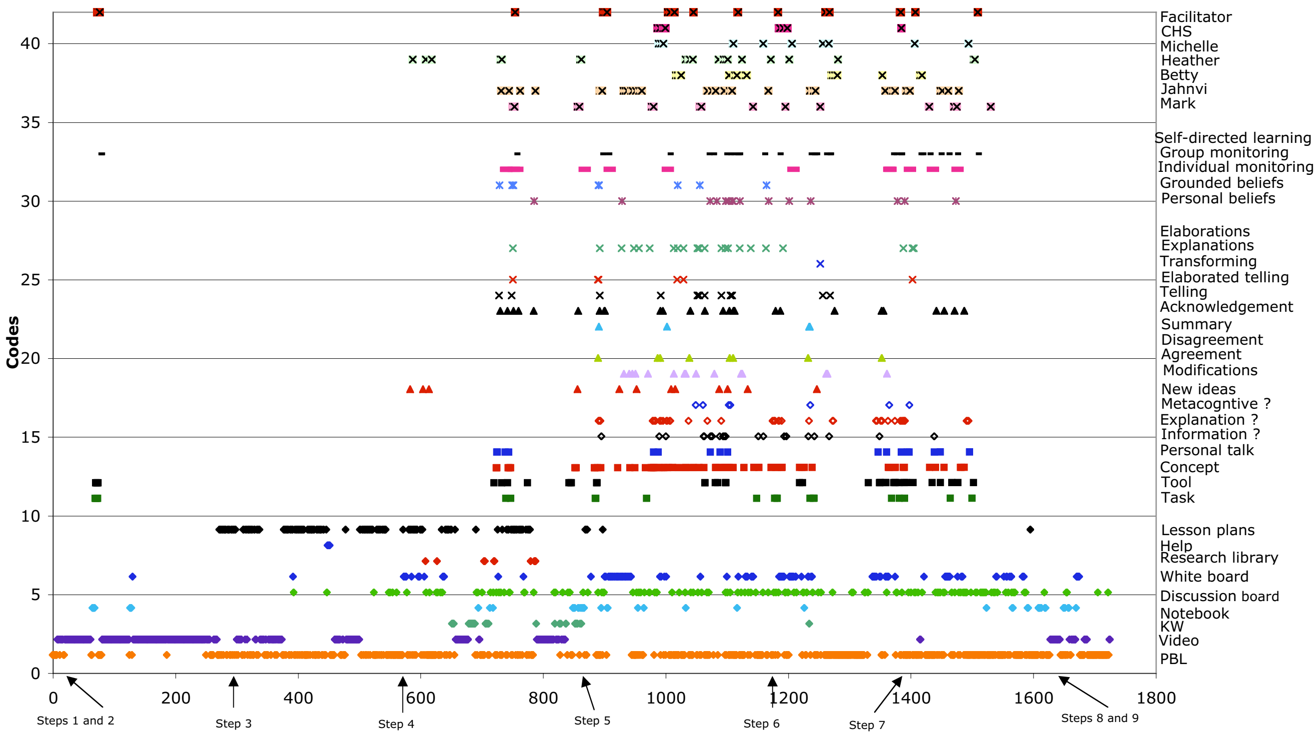

Figure 3: Problem 2 CORDTRA

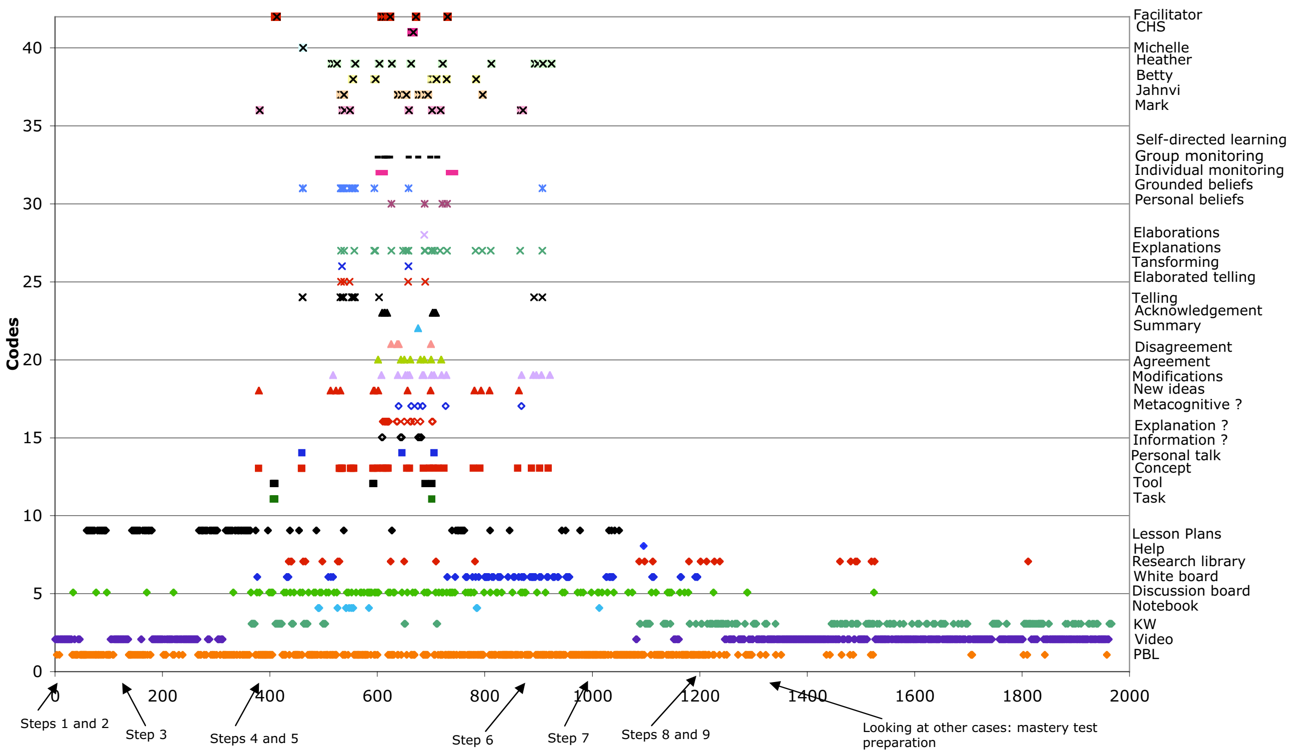

Figure 4: Problem 3 CORDTRA

view. Together with acknowledgements and agreements, there were also some disagreements during the conversations. CORDTRA shows that justifications shifted from personal-belief based to clearly evidence-based. The combination of these two trends may mean that students were more comfortable in online conversation. It may also suggest that the students understood the "rules of the game" that in order to convince someone that their argument is stronger, merely a strong personal belief may not be enough.

While the CORDTRA analysis examined the evolution of group collaboration and discourse patterns from Problem 1 to Problem 3, a look at the individual and group mean scores showed similar trends across the problems. The mean scores ranged from 9.80 (SD = 1.09) out of 12 possible points for Problem 1 to 10.80 (SD = 0.45) for Problem 2 to 11.00 (SD = 0.00) for Problem 3. The group ranked second in the class on the final learning outcomes.

A synergistic look at the collaboration data and the learning outcomes suggests that along with improving patterns of communication among groups, the group solution also improved in quality. In addition, each group member engaged in online conversations to a greater extent and scored higher points by the last problem. Since the primary focus of this paper is on examining the processes whereby tools and activities mediate learning in a group, making causal attributions for this learning or drawing statistical conclusions is beyond the scope of this paper.

REFLECTIONS FROM THE FACILITATOR

Most college students are taken by surprise when faced with a course that is mainly anchored in a PBL format (Hmelo-Silver, 2000). The group chosen for analysis in this study was no different. The second author of this paper (AN) acted as the facilitator for this group, both in face-to-face discussions and online collaboration, and maintained a journal documenting the functioning of the group over the semester. In this section, we discuss some of the insights of AN on how and why the group functioned differently from problem to problem and how her role changed as well.

At the first meeting with this group, the apprehension and uncertainty on each student's mind as they started on their first problem was apparent. The groups worked on two problems face-to-face before using the online environment for the last three problems. We expected that the first two problems would serve as a good "warm-up exercise" before the switch to the online set-up. However, in the case of this group, it was not so. The group had barely started understanding the PBL process and the switch to the online set-up completely threw them off. For the first online problem, there was little demonstration of any online communication and participation. They tended not to question each other; rather each student posted their research and proposals without much interaction with other group members. In fact, when AN asked certain questions to try to get the group discussion going, one of the group members, Jahnvi, responded:

> I understand that you are there to help. However, I just try to clarify anything that you may have missed during our group discussion. I always get nervous that when you ask questions, our group may be on a totally wrong path to solving this problem or else you would not be questioning it. Therefore, I just try to verify what we're doing is ok.

AN subsequently responded:

> The reason for my asking you questions is to see whether you can clearly explain what you're referring to and can adequately justify it. So take it easy and take my cues as constructive feedback- Whenever you go totally on the wrong path, you'll find me spending more time in your group.

On the first online problem, this group had not completed their group solution and was quite unsure of what they were supposed to do when asked to present at the class poster session. They were given extra days to complete their work. The online participation recorded for this group occurred largely after the class deadline, Even so, the level of participation on the first online problem was quite limited compared with the next problem. This was probably because they were still trying to understand the process and expectations of the task. The group found it hard to ask and answer questions in the asynchronous environment. Their first solution was not terribly innovative but they did begin to see how they should be tackling the problems and communicating with each other online.

When this group moved to the second online problem, they were more than caught up with the other groups. The sheer embarrassment of not being ready with their presentation at the first problem and being able to identify *why* that happened led them to strategize well for the next problem. Understanding the expectations of the task, the steps essential to meet those expectations, and a more accurate projection of the time and effort needed to succeed at this task led them to plan better and expend the necessary effort. All students took ownership of the task, laid out the components of the problem clearly, and planned their group solution after thoughtful research and prompt communication with one another. In the first problem, AN was trying to get them to understand the task and model questions they might ask of each other. By the second problem, they were doing most of that, allowing AN to ask them higher-level questions and at times just stay out of the conversation. For example, in Problem 2, AN was able to focus on asking questions that pushed the students to consider how different types of instruction affect learning "now that you've listed three types of learning and the activities and assessments for each, what might be the advantages of using one over the other..how will each type of learning and/or teaching facilitate understanding…" In fact, one student in the group started asking the very same questions asked by the facilitator at an earlier discussion. Sometime during the second problem, the students were discussing the proposed activities and the need to choose between them. Jahnvi gives the rationale for why she thinks her idea is worth keeping. Her use of language shows that she understands the concepts and that her ideas are based on research evidence. At the end she asks a question inviting other group members to do the same for their proposals in question:

> Self-explanation is supported by research on explanation based learning. Using real-life examples is supported by example based learning (My research). Also, the students must explain it to other students using their own words and to study it using other reference materials, which incoporates them in active learning (Betty's research). The assessment will meet the objective of understanding the concept and also is supported with research on transfer. So do we want to keep it or go with the other activity? What is the other activity supported by?

The second problem was, by far, the most complicated problem of the semester and this group participated in the online discussion with a strong commitment and motivation to succeed. When they moved to the third problem, the group had a clear understanding of the task and had a set of strategies that they could use to tackle the given problem. They also had somewhat defined roles wherein two students acted as joint leaders trying to make sure that the group was on task and on target. Two other students in the group contributed by identifying relevant research and connecting previously learned information to the current problem. Even the one student who didn't participate as much in the first problem started engaging and communicating in the online discussion board. Overall, the group had converged in their collaborative efforts and worked together effectively and efficiently. The two "leaders" of this group were amongst the top five students in the class and the other three also received high grades. A major factor contributing to this group's success was their motivation and willingness to learn from their mistakes.

As with the students in the group, the functioning and role of the facilitator changed across the three online problems. When the group failed to present the group solution at the gallery walk in class, AN held a private meeting with the group to understand what went wrong. Based on this meeting, it became clear that the students did not understand what was expected of them and how to go about planning a group solution. In addition, the group was unskilled at questioning one another and carrying on an online conversation. AN clarified the task expectations as well as expressed her concern at the limited interest and participation from the group and offered her help to resolve any conflicts or misunderstandings with the task. Once the students were attentive and expressed an interest to rectify the mistakes, AN encouraged and motivated them to work on the problem for an additional number of days so that the group could come up with a reasonable solution. During the first problem, AN spent a lot of time providing words of encouragement, answering technical questions about the STEP site, and modeling different questions that could elicit reflective answers and promote collaboration. In her attempt to make students participate and make their thinking explicit and visible she posted the following comment on the white board in response to one of the proposals: "elaborate on each of these forms of assessment and relate it to the research. FOr [*sic*] example, what will a lab report look like and how will that demosntrate [*sic*] what students' have understood. What types of assessments do each of the above mentioned fall under?" Prompt response and feedback to e-mail and online discussions helped the students to move at a faster pace and develop their group solution. By the second problem, the focus largely shifted from managing the task to getting the students to think intellectually, find reliable sources of evidence, justify their proposals with appropriate research, and continue with higher-level reflective questions. AN also encouraged disagreements on issues among group members and pointed that disagreeing and debating with evidence was a useful component to expanding one's thinking. By the last problem, AN spent even less time facilitating the group as the group discussion was initiated and continued by the students in the group. Overall, the synergistic effort and commitment of the group and the facilitator contributed to the success of the group in this PBL course.

DISCUSSION

Our analyses demonstrate that group collaboration in online PBL evolves and becomes more complex over time. Both the evolution of student discourse and use of the video cases change over time. Although the use of other tools remains relatively unchanged throughout the semester, the use of video as a tool is different in every problem. It is possible that as students gain more experience with the online PBL course, they get better at watching videos and noticing the details they initially do not pay attention to. By noticing more details appropriate for the group discussion, they eliminate the need to go back and view the video again during discussions. It is also possible that as the semester goes on, the students learn that their focus is not a "video" per se, but the "problem" that they need to solve and that is presented in the video. Thus, once they are familiar with the problem they learn to shift their focus from the video to the problem itself.

The CORDTRA diagrams indicate the dramatic change in the interaction pattern after Problem 1. There are a few possible explanations for these changes. The reflections of the facilitator indicate that during the first online problem students were lost and did not realize that active involvement in the problem-solving process was necessary for successful online collaboration. By failing to solve Problem 1 effectively and on time, the group was forced to re-think their performance and consider the reasons for doing poorly. The facilitator continued to show them what was expected of them and made them understand what the task required them to do. This renewed understanding of the task motivated them to engage with Problem 2 at a different level. The modeling of various questions provided by the facilitator allowed the group to both ask a variety of good questions and appropriate some of the necessary language. In addition, data depicted in CORDTRA diagrams suggests that the usage of tools (such as the KW) in subsequent problems mediated student learning. CORDTRA shows that as the group's learning progresses, the usage of tools not only shapes the interactions but is also transformed during the activity.

One can argue that it is natural that students improved in their performance as the semester progressed. The improvement in performance may be due to the fact that the students figured out the "rules of the game" and in subsequent problems knew exactly what to do and how. It is possible, however, that on top of this natural tendency to improve due to the familiarity with the task, in problems 2 and 3, the students put in more effort, engaged more with the task and as a result saw more value in it. This is corroborated by the reflections of the facilitator. In addition to increased student effort, the encouragement and support provided by the facilitator may have contributed to the performance leap between the problems.

The role of the facilitator, thus, seems to be extremely important in an online learning activity. The facilitator reflections help us see "between the lines" of CORDTRA diagrams and help us understand what indeed happened during the learning process. For example, the facilitator insights made it clear that much of the work on Problem 1 happened after the poster session and that the students needed that opportunity in order to fully understand the task. The facilitator also helped explain why students kept working online at the end of Problem 3. This explanation confirms the belief that the task of preparation for the final test was meaningful. It helped the students master the material by engaging in learning even after the last problem was solved.

Learning collaboratively, yet asynchronously has specific challenges. While this group is a specific example of what the students go through during the online learning, some general approaches towards asynchronous discussions can be seen from the example of this group. The facilitator reflections clearly indicate that the group would not have been successful had they not understood that working online requires a different level of commitment than face to face meetings. It requires an increased responsibility in being prompt to reply to other members, increases the dependency on others and on the technology that students are working with. It also places a certain responsibility on the facilitator. The facilitator needs to recognize the importance of encouragement for the students and provide prompt feedback. The facilitator also needs to be patient in explaining the importance and function of multiple tools that the system provides.

The fact that students need to engage in learning the online tools at the same time they are engaged in learning the material may be of special challenge to both the facilitator and the group as students experience additional cognitive load. For the students, there is a tension between learning to use the eSTEP tools and engaging in PBL. It is critical that course instructors adequately prepare and support students in working with the online system and its multiple tools to ease students' transition to the online learning environments.

Online PBL environments can extend facilitation resources and allow a single facilitator to work with many groups (Steinkuehler et al., 2002). This is important in the typical class when one instructor may have a number of groups working at the same time. PBL online allows the facilitator to respond promptly to many groups which is impossible in large face to face classes. Another advantage of online environments is the discussion trace. Such archives become an additional resource that the students can draw upon when forming their solution to the problem. The availability of the discussion trace also assists the students in monitoring their progress as it allows students to see what they have already done and what else needs to be accomplished.

Finally, online learning formats such as eSTEP provide effective scaffolding through tools that help communicate the problem-solving process, elicit student articulation, and provide hints about the kinds of concepts that need to be explored (Collins et al., 1989; Hmelo-Silver, in press). In the case of the eSTEP system, the steps themselves serve as a scaffolding device that help students know what is coming and what else needs to be done before the problem is completed. PBL online also allows for the creation of both personal and group spaces, which are essential for the processes of internalization and externalization. The white board also triggers externalization by providing each student with a place to not only propose their ideas for solution, but also comment on each other's proposals. This helps make their thinking visible and open for renegotiation.

Tools such as CORDTRA provide specific mechanisms for thinking about learning in light of activity theory. Reflections provided by the facilitator give an additional perspective into group and help understand how a group engages in collaborative knowledge construction. Blending the two perspectives can help us understand how different aspects of an activity system mediate collaborative knowledge construction.

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A Pilot Study of Computer Supported Learning by Constructing Instruction Notes and Peer Expository Instruction

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Abstract. Learning by teaching has been extensively studied in education and psychology research. However, there has been relatively less effort in this research avenue in CSCL research. Computer supported learning by teaching, as a genus of CSCL activities, is expected to draw more attention in the future. In this pilot study, we propose a model of computer supported learning by teaching that involves peer tutors in preparing their instruction notes and teaching their peer tutees verbally. Collaborative learning is incorporated in our pedagogical design. As an initial investigation and for future improvement of our design, we conducted two experimental trials in a graduate-level course. This paper discusses the design of this model and reports our findings from the experimental trials.

Keywords: computer supported learning by teaching, computer supported peer tutoring, peer teaching, reciprocal peer tutoring, learning by teaching

INTRODUCTION

Students teaching students, or peer tutoring, is a pedagogical strategy studied extensively in the education research. It has been found that having students teach each other increases their achievement at various educational levels (Cohen *et al.*, 1982; Falchikov, 2001; Rohrbeck *et al.*, 2003). Several studies have further shown that tutors academically profit more than their tutees, and the gains are not only from the teaching activity, but also from the pure expectation of a later teaching demand (Bargh & Schul, 1980; Benware & Deci, 1984).

Chan (2004) indicates that teaching represents a repertoire of activities consisting of learning about the materials, composing teaching materials, conducting face-to-face teaching, monitoring learner's work, assessing learner's learning outcomes and affective status, and reviewing their own teaching process. Learning by teaching can be of varied forms, and when peer tutors are involved in different teaching activities, they would learn in different depths and with different perspectives (Chan, 2004). A group of international researchers envision that a computing device will be as indispensable as a pencil for a student in the future (www.G1on1.org). Given such an inevitable trend, Chan points out that the intention of a comprehensive Computer Supported Learning By Teaching (csLBT) model is to have peer tutors cover the teaching activities as many as possible by the supports of one-on-one (1:1) educational computing classroom where every student has a computing device with wireless communication support.

There have been various efforts in designing intra-class peer tutoring, but mainly for "monitoring learner's work" activity; that is, having peer tutors monitor and give immediate feedback or help when tutees are doing exercises, for example, Class-Wide Peer Tutoring (Greenwood *et al.*, 1989), Reciprocal Peer Tutoring (Fantuzzo *et al.*, 1992), and ASK to THINK-TEL WHY (King, 1997). These approaches are similar in the way that they conduct reciprocal tutoring by asking tutees questions which are either structuralized or provided from the class teacher and are held in the situation that both tutors and tutees have read or been taught about the target subject.

This pilot study proposes a model of csLBT which addresses on learning by constructing instruction notes and peer expository instruction. The proposed model involves students in three teaching activities—learning about the materials, composing teaching materials, and conducting face-to-face teaching—by the supports of 1:1 educational computing classroom. Collaborative learning plays a crucial element in our pedagogical design. Two experimental trials were conducted in a graduate-level course to explore (a) how this model can motivate tutors to learn, (b) what and when tutors and tutees would benefit from the model, and (c) how much students would prefer this model to be used in their courses regularly.

MODEL AND SYSTEM DESIGN

There are three phases in the proposed csLBT model. The first two phases are related to learning by teaching and the last phase is to complement the first two phases with instructor-led discussion.

Preparation phase

This phase consists of four sub-phases: (1) *Learning about the materials*. The class instructor prepares materials for two different topics, then arranges the class into two groups and assigns each group to study a topic for preparing to teach the other group. This design is for every student to has equal chance of learning by teaching. With the intention of explaining to others, students would pay more efforts in their individual learning. (2) *Constructing individual instruction notes*. Every student has to compose instruction notes after studying the assigned material and submit to the csLBT system. This step facilitates tutors to identify and organize main ideas, and shapes their thoughts concretely. (3) *Peer assessment.* Peers in the same group assess each other's instruction notes anonymously. Not only this step can release the teacher from grading works, but also provide tutors the chance to reflect on their own products. (4) *Collaborating for common instruction notes*. Instead of using individually designed instruction notes to teach, students are paired in the same group and each pair has to "merge" their notes into a common one for their later teaching. The sub-phase is designed for facilitating tutors to explain their own rationales, coordinate and integrate alternative perspectives, and produce a better instruction note than they have down individually. Figure 1 shows a system to support these sub-phases.

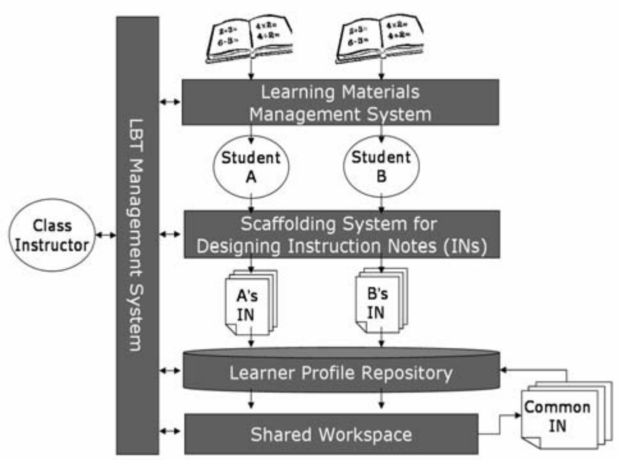

Figure 1 System design of the *preparation* phase

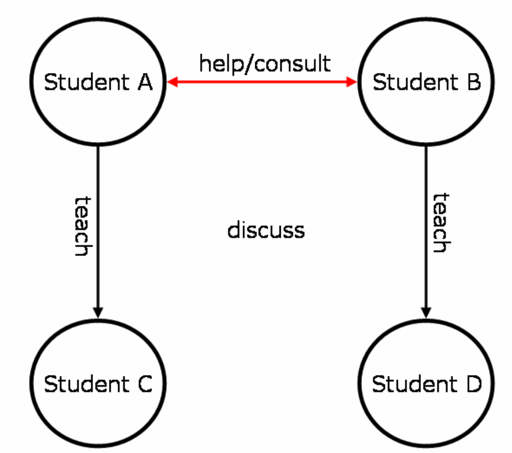

Figure 2 The interaction model during the *peer teaching* phase with the supports of 1:1 educational computing classroom

Peer teaching phase

This phase consists of two sub-phases: (1) *Conducting expository instruction*. As demonstrated in Figure 2, A teaches C and B teaches D where C and D are from the other group. A and B are teaching with their common instruction notes and helping each other. The one-on-one tutoring design is for augmenting each student's benefits by the intensive interactions. And the design of two tutor-tutee pairs as a group helps discussion when alternative perspectives are needed. (2) *Answering questions and group discussion*. Every student answers questions distributed by the class instructor and then A, B, C and D, as a small group, share and discuss their answers. During this phase, students interact with each other face to face with the supports of 1:1 educational computing classroom where all students are equipped with wireless-enabled laptops or Tablet PCs. These devices allow students for accessing and presenting learning materials and the common instruction notes, and sharing and revising the answers in the second sub-phases.

Instructor-led discussion phase

The class instructor explains the answers of the questions in the peer teaching phase and gives complementary instruction if needed. With the supports of 1:1 educational computing classroom, the instructor can view all reported answers and then adjust her explanations and complementary instruction. She can also present some selected student answers and hence enrich the class discussion. We expect the *answering questions and group* *discussion* sub-phase and *instructor-led discussion* phase are especially important for the peer tutees as these phases verify the qualities of peer tutoring and their own learning and provide the second chance to be taught.

EXPERIMENTAL TRIALS AND INITIAL INVESTIGATIONS

Students enrolled in or auditing a graduate-level seminar course on "Intelligent Tutoring Systems" participated in these experimental trials. A total of 26 graduate students, including seven doctoral students and two postdoctoral students, participated in the first trial, and half of them taught the other half. In the second trial, 22 students in the class, including six doctoral students, participated owing to absence of four students. Those who were tutees in the first trial acted as tutors in the second trial. Participants were grouped and paired randomly. No incentives, such as increasing grades or passing exams, were given for their participation so that we can see how the model itself can motivate students.

The *preparation* phase took participants two weeks before the *peer teaching* phase. In each trial, both *peer teaching* phase and the *instructor-led discussion* phase were held in a three-hour class meeting. The *conducting expository instruction* sub-phase took one and half hours, the *answering questions and group discussion* sub-phase took one hour, and the class instructor led a whole class discussion about the questions and provided topic review in the rest class time.

The prototype of csLBT system was supported by two existed systems. EduX (Chang *et al.*, 2003) supports activities in the *preparation* phase via Internet. Digital Classroom Environment (DCE) (Deng *et al.*, 2004) supports the other two phases and every participant is equipped with a wireless enabled Tablet PC. The major functions supported by DCE are questions distribution, individual answers reporting and storage, sharing reported answers among the small group members, and viewing all the reported answers—a function for the class instructor. Figure 3 is a screen shot of DCE drawing panel functioning in the share mode—all group members' answers are displayed in the small boxes in the bottom and can be displayed in the bigger box for shared workspace or legibility by clicking one of those small boxes. Any modification will be displayed synchronously. Figure 4 depicts members in a small group revisiting the materials after finding the differences among their answers via the share mode of DCE.

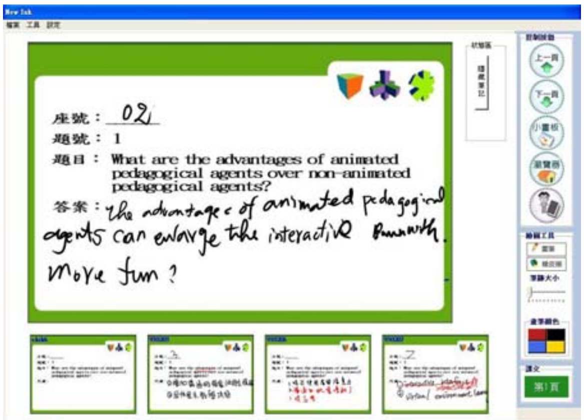

Figure 3 A student using DCE (share mode) to share and discuss answers with other members.

Figure 4 Small group members in their learning during the discussion session

After the experimental trials, 12 participants were interviewed about what they learnt and what had driven them to learn in each sub-phase. All the interviews were tape-recorded. Some selected feedbacks were excerpted in Table 1.

Table 1 Some feedbacks from participants during the interviews

Sub-phases	Excerpts from the interviews
1-1 Learning about the materials	*"…If you can't teach yourself, how can you teach others? So I tried my best to understand the assigned material."* (motivation for full comprehension) *"When I have to teach somebody, I have to make sure the ideas I get from the assigned material are 'really' what the material means, so that my tutee won't get wrong ideas because of me, or I'll be very sorry…"* (commitment to teach correctly)
1-2 Constructing individual instruction notes	*"Besides the slides* [instruction notes] *shown on the laptop, I additionally provided more detailed summaries in my instruction scripts…"* (paying more efforts) *"As we were going to compose the notes for others to learn, so I structured my notes so that they are composed of several sessions."* (creating ways for organizing knowledge)
1-3 Peer Assessment	*"The assessing rubrics should have been provided earlier…because they could have served as a guide for composing my own instruction notes."*
1-4	*"We found the content* [some concepts] *was talking about the same things, although their*

Collaborating for the common instruction notes	*terminology or perspectives were different. So we put them together and linked with the similar concepts mentioned in the previous classes…"* (linking and integrating ideas) *"We arranged them* [instruction notes] *chronologically, talking about the origins, the evolution, and the problems it was facing…"* (re-sequencing according to a certain structure) *"These are talking about functions and usages, and those are talking about solutions…"* (categorizing topics) *"I really enjoyed the collaboration with my partner for working out our common instruction notes. It's not just like labor division—the usual way we use for tasks like group reports. This is a real collaboration."* (positive affective outcomes and intellectual collaboration)
2-1 Conducting expository instruction	*"My tutee asked something I couldn't explain according what I learnt, then I revisited the original material, and then I realized I had misunderstood that part."* (repairing knowledge) *"My tutee asked a question that I couldn't answer. We checked the paper together and found it was mentioned in the paper."* (finding missing knowledge) *"After I provided further elaboration for an idea that my tutee found confusing, my tutee kept nodding and saying 'I got it!' And that made me feel so great… "* (sense of achievement) In the views of peer tutees: *"I was fully concentrated during the whole process. Because, you know, how can you be distracted when you're the only person whom somebody is looking at and talking to?"* (social obligation and hence concentration) *"I asked every question emerged from my mind when my tutor was teaching. Although he was teaching me, I felt we were more like partners and we were discussing. I usually don't ask many questions in the class because they might be regarded as silly questions."* (individualized instruction)
2-2 Answering Questions and group discussion	*"The main sense of achievement came from when my tutee answered the questions correctly—that meant my teaching worked…"* (sense of achievement) *"I felt sorry when the tutees had no ideas about the answers—I missed mentioning that part." "I think that tutors learn more in such activities…It seemed that my tutee couldn't digest what I had taught because he failed to answer so many questions…"* (frustration because the tutor could not tutor his tutee well enough) In the views of peer tutees: *"My tutor taught me a lot of things, and those things were scattered in my brain unorganized. Answering the questions helped me categorize the knowledge I had just been told, knowing what belongs to what…"*
3 Instructor-led discussion	In the views of peer tutees: *"Explanations from the instructor were very important, because there were some questions even my peer tutor was not sure about the answers. And I also would like to learn more from the perspectives of the instructor as well as the other small groups."* *"The instructor's explanation was well-organized, so I got a clearer picture about the topic my tutor taught me."*

Besides the interviews, participants were requested to fill in a questionnaire asking them to rank the value of each sub-phase for their learning, from both perspectives of the tutor and the tutee. From the tutor's perspectives, participants ranked the *learning about the materials* phase the highest, the *constructing individual instruction notes* and *collaborating for the common instruction notes* as the second, then the last three sub-phases but in the order of *conducting expository instruction*, *instructor-led discussion*, and *answering questions and group discussion*, and *assessing peers' instruction notes* as the last. From the tutee's views, however, the ranks of the last three sub-phases (in-class sub-phases) are reversed, that is, *instructor-led discussion* phase the highest, then *answering questions and group discussion*, and *conducting expository instruction* as the last.

Another item in the questionnaire is how often the student wishes to use this model in a course. Only five percent of participants wished to use it every time the class meets. 55 percent of participants agreed that this model can be used about half of the times the class meets. 35 percent of participants preferred using it less than half of the course. No one wished not to use this model in any class. Five percent of participants left this item unanswered. In the interviews, participants explained that although this model facilitated learning, the preparing phase was time-consuming for tutors.

DISCUSSION AND FUTURE WORKS

Many positive impacts on peer tutors' learning, both in affective and cognitive domains, are found from the interviews. They were motivated to study carefully and thoroughly because of the commitment to teach correctly and to help others. This kind of intention to comprehend, as Brown (1988) suspected, may be the critical reason that makes the "reciprocal teaching" strategy successful. They sensed satisfaction when clearing their tutees' confusions up and helping them answer the instructor's questions correctly. They *cared* about how their tutees learnt. Higher-level cognitive gains, e.g. actively linking, integrating, organizing the knowledge they learnt, mainly came from the phase of merging two different instruction notes—just as one interviewee said: "*It is the real collaboration*." By teaching others, misunderstandings were repaired and knowledge was consolidated. Moreover, positive learning attitudes were also elicited because tutors have intensive interactions with their partners and tutees. We also find that, despite age and seniority differences, the efforts that peer tutors paid for preparing teaching were not affected by whom they were going to teach, although they felt pressured when their tutees are more senior, for example, doctoral students.

From the interviews with tutees and their questionnaires, however, we found that peer tutees would not have been satisfied if they had just been being taught by peer expository instruction. After being tutored, tutees found that they are more eager for having the opportunity of actively organizing the knowledge just newly learnt and treasure the instructor's inputs in the last phase as this ensures and enriches what they learnt. This finding supports our expectation that the two designs, *answering questions and group discussion* sub-phase and *instructor-led discussion*, will be especially important for tutees' learning. Nevertheless, it also suggests that a basic tutoring training can and should be supported by the system, or students may not know how to perform an effective instruction. Hence, scaffolding mechanisms supporting peer tutors for their preparation and teaching processes are essential for the csLBT system and will be one of our future works. Another future work of this research is to engage tutees both in the preparation and peer teaching phases, instead of being tutored passively.

Generally speaking, this pilot study suggests that by involving students in composing instruction notes and teaching their peers, graduate students can learn actively and both tutors and tutees are immersed in such learning context, even though there is no incentive provided. Therefore, further development is worthwhile for building more useful tools and scaffoldings for this csLBT. However, there are some issues that have to be seriously considered when designing such a system. First, the works for tutors in the preparation phase are time consuming. Second, the class instructor may concern about student's tutoring quality. He is sure what he said is right in the class though he does not know whether students understand or not. But in the proposed csLBT model, he is not fully confident whether student tutors can correctly teach the materials. Finally, the learning chances may be unequal between peer tutors and peer tutees since peer tutors may gain more than their tutees. Some carefully designed experiments comparing the learning effects of csLBT for graduate students and other common teaching strategies should also be conducted.

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Measuring Motivation in Collaborative Inquiry-Based Learning Contexts

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Abstract. This paper argues that for understanding motivation in collaborative inquiry-based learning settings, there is an urgent need to develop new instruments that can capture the impact of the changes from the learning of well-defined content to open-ended inquiry and from individual learning to group-based learning on learning motivation. It reports on the development of such an instrument, the Collaborative Inquiry-based Project Questionnaire (CIPQ). Confirmatory factor analysis of the CIPQ data on six independent groups (n=269, 235, 173, 192, 300 and 254) of students who participated computer-supported collaborative learning (CSCL) projects has consistently yielded a five-factor model of motivation (Project Work, Social Learning, Task, Reinforcement and Social Pressure factors). The validity of CIPQ was indicated by the empirical relationship found between the five factor scores and independent measures of the levels of project engagement of the students.

Keywords: Motivation, collaborative inquiry-based project work, scale development

INTRODUCTION

Why do some students try harder than their classmates in learning? Why are some students more willing to strive for difficulties and challenges? Why is it that some students rarely engage themselves in deep learning? Motivation is a construct that refers to the inner psychological process that provides a behaviour its energy and direction (Reeve, 1996). Studies of motivation that aim to answer these important questions have become an important research area since 1970s. A number of well known theories about motivation have been developed, such as self-determination theory (Deci & Ryan, 1985), goal models (Ames, 1992; Pintrich, 2000), expectancy-value theory (Eccles et al., 1983), self-efficacy (Bandura, 1986; 1997) and self-theories (Dweck, 1999). They were theories about learning motivation in traditional settings in which learners engage in well-defined learning tasks individually, following detailed instructions provided by teachers.

In recent years, collaborative inquiry-based learning, often organized as project work in schools, has become increasingly prominent as a response of schooling to the challenges of the 21st Century (Scardamalia, 2001; Law, 2004). This new form of learning setting differs from traditional settings in several important ways: instead of learning individually through short and specific subject-related tasks, students have to work with others in teams and inquire into ill-structured questions over extended periods of time; learning outcomes depend not only on individual efforts but even more on group collaboration; instead of learning with well-defined goals, learners have to cope with many uncertainties in their inquiry processes and often have to determine their own benchmarks for assessment. What are the impacts of such changes on students' motivation? Would the motivation structure remain the same? If not, how is motivation structured in collaborative inquired-based learning settings? How should the concept of motivation be operationalized and measured in these new contexts? It is argued that the current motivational approaches and their instruments developed in traditional learning settings are insufficient to capture the impact of inquiry and collaboration on learning motivation. There is an urgent need to develop an instrument for measuring motivation in collaborative inquiry-based learning contexts as the first step to develop an explanatory model on motivational structure in these new contexts. This paper reports on the development of an instrument to address this need. More specifically, this study aims to develop an instrument for revealing the latent motivational factors of students in the new learning settings and to investigate their construct validity through triangulation with other indicators of students' engagement in the collaborative learning tasks.

THE ONTOLOGICAL STATUS OF MOTIVATION IN DIFFERENT MOTIVATION THEORIES

As mentioned, there has been a lot of exciting theoretical developments in studies of motivation such as the self-determination theory (Deci & Ryan, 1985), goal models (Ames, 1992; Pintrich, 2000), expectancy-value theory (Eccles et al., 1983), self-efficacy (Bandura, 1986; 1997) and self-theories (Dweck, 1999) over the last two decades. Underpinning these different theories are different ontological and structural assumptions about motivation, leading to differences in the stability of motivation as measured across situations as well as the dimensional aspects captured in understanding motivation (Murphy & Alexander, 2000).

Some theories conceptualize motivation as a personal trait which remains constant across situations. For example, one of the major claims of self-theories is that motivation is very much dependent on whether the learner believes that intelligence is malleable (incremental) or fixed (entity) (Dweck, 1999). Learners who perceive intelligence as a changeable quality through learning would be more motivated than those who perceive intelligence as a fixed innate quality. On the contrary, some other theoretical approaches, such as self-efficacy and expectancy-value theory, conceptualize motivation as task-specific states which change from task to task (Bandura, 1997; Eccles et al., 1983). Self-efficacy is a motivational construct associated with a person's *belief* in his/her self-competence in completing a specific task and a stronger belief in self-competence would result in a higher motivation for that specific task (Bandura, 1997). In Wigfield & Eccles's (2000) expectancy-value theory, the *expectancy* construct is similar to Bandura's self-efficacy and the *value* construct refers to the students' value judgment towards a task, including the perceived importance, intrinsic value and utility value of the task and the effort they are willing to pay to accomplish the task.

There is a third group of theories which conceptualize motivation as a construct between the above two ontological extremes such that it is sensitive to the learning contexts and yet still carries some stability over time and situations (Pintrich, 2000). The achievement goal construct of the goal models and the self-determination theory are two examples. Achievement goal construct associates motivation with individuals' beliefs about the learning activities concerned, such as task purposes, criteria for success and what constitutes effective learning strategies to achieve the perceived successfulness (Pintrich, 2000). Self-determination theory conceptualizes motivation as a two-dimensional construct comprising the *task* and *reinforcement* dimensions. The task dimension accounts for people's intrinsic motivation to engage in a particular activity because of the positive feelings inherent in doing the task itself (White, 1959; Woodworth, 1921). On the other hand, the reinforcement dimension refers to extrinsic motivation associated with the external and environmental drives (Deci, 1972; Lepper, Greene & Nisbett, 1973). While the self-determination theory builds upon the classic model of intrinsic and extrinsic motivation, it also breaks away from the perspective of taking intrinsic and extrinsic motivation as competing dichotomous constructs. Instead, the theory proposes a taxonomy of external motivations with different levels of internalization of task values and autonomy of behaviour, from the least motivated "external regulation" to "introjection", "identification" to "integration" (Deci & Ryan, 1985). The theory also suggests some mediating factors influencing students' levels of motivation such as students' perception of self-competence and the value that they place on the tasks (Deci & Ryan, 1985).

The differences in conceptualizations of motivation between these approaches are also reflected in the designs of the respective self-report instruments. Dweck and Henderson's questionnaire (1988) for measuring respondents' belief on intelligence based on the self-theories paradigm is a context-free scale. The self-efficacy scale for academic achievement (Bandura, 2001) and the instrument for assessing children's ability beliefs and subject task values (Wigfield & Eccles, 2000) are context-specific instruments which always refer to specific subject domains in their designs. On the other hand, both the scales for measuring goal orientation developed by Niemivirta (1998) within the goal models paradigm and the Academic Self-Regulation Questionnaire (SRQ-A) developed by Ryan and Connell (1989) within the self-determination theory paradigm frame their questionnaire items within a general academic context such as studying for schoolwork or doing homework.

LEARNING MOTIVATION IN COLLABORATIVE INQUIRY-BASED TASK CONTEXTS

Despite the differences between their conceptualizations and instrument designs, all the discussed approaches operationalize motivation among three important dimensions in traditional learning contexts, including the *self*, *task* and *reinforcement* dimensions. Self-theories, self-efficacy and the expectancy construct in expectancy-value theories all capture the self dimension by stressing the importance of the learners' beliefs on self-intelligence or competence. The task dimension is integral to the goal models, self-determination theory and the value construct in expectancy-value theories, and refers to the intrinsic motivation derived from engaging in a task or the learner's perceived importance of the task. The reinforcement dimension is captured in the classic intrinsic-extrinsic dichotomy and is also integral to the self-determination theory as extrinsic motivation. However, when school learning settings change to feature prominently collaborative inquiry-based activities, does the importance of the self dimension in motivation remain the same? Do beliefs on self-competence still matter? Would the perceived competence of groupmates influence the learner's attitude towards the learning tasks? Is reinforcement still an important dimension in learning motivation when the outcome pertains to the group instead of to the individual? Furthermore, when the learning task changes from being short, well-defined and with definite solutions to being extended, ill-structured, full of uncertainties and without clear unique solutions, what are the impacts of these changes on the task dimension of motivation? The existing instruments for the measurement of motivation cannot capture the impact of open-ended inquiry and collaborative learning.

There are a few published studies that investigated motivation in this kind of new learning contexts, for example, the work of Järvelä and Niemivirta (2001) and Veermans and Järvelä (2004). However, even for these studies, the research instruments adopted were still those developed for studying learning motivation in traditional classrooms. This further highlighted the need for a research instrument that can help us to understand more adequately motivation in collaborative inquiry learning contexts. This paper reports on some initial work done in the development of such an instrument.

INSTRUMENT DEVELOPMENT

The current project conceptualizes motivation as a construct that it is sensitive to the learning contexts and yet still carries some stability over time and situations, which is similar to the perspective adopted in the self-determination theory. More specifically, motivation is taken as the context-induced structural tendencies of the individual to a learning situation (Niemivirta, 2002; Pintrich, 2000). This conceptualization assumes that students' motivation in collaborative inquiry-based learning settings to be a kind of chronic structure which carries a general level of stability across situations, yet still sensitive and malleable according to contextual factors and dimensions, such as the specific group dynamics or inquiry topics involved.

In this study, a self-report instrument, Collaborative Inquiry-based Project Questionnaire (CIPQ), was developed in two language versions, English and Chinese. The questionnaire was designed to examine whether there are additional structural components of motivation in addition to the task and reinforcement dimensions. Its 24-item earliest version was modified to a 20-item version according to the participants' on-site responses as well as the statistical analysis which verified the validity of the instrument (Chow, 2003). Eight of the 20 items in CIPQ were adopted from the Academic Self-Regulation Questionnaire (SRQ-A) (Ryan & Connell, 1989).

Table 1 Question Stems and Response Items in CIPQ

Question stems & items	
(A) Why do I try to do well in school?	
1.	Because that's what I'm supposed to do.
2.	Because I will be scolded by my parents or teachers if I don't do well.
3.	Because I enjoy doing my classwork.
4.	Because I might get a reward if I do well.
(B) Why do I work on my class work?	
5.	Because I want the teacher to think I'm a good student.
6.	Because I want to learn new things.
7.	Because I'll be ashamed of myself if it didn't get done.
8.	Because I enjoy doing my school work well.
(C) Why do I participate in project work?	
9.	Because I like to work with my classmates in group activities.
10.	I participate in project work because it's fun.
11.	Because it's important to me to do project work.
12.	Because if I don't participate, the friendship between my friends and I will be affected badly.
13.	Because working in group (compare with working individually) allows me to tackle more complex project topics.
14.	Because participating in project work can help my academic learning.
15	Because if I don't participate, my groupmates will blame me.
16.	Because compared to learning by doing homework, it is more effective to learn by doing project work.
17	Because I don't want to be perceived as a burden to my groupmates.
18.	Because there are many chances for discussion and sharing of ideas by working in groups.
19.	Because learning in a group allows me to have more courage to investigate more complex topics.
20.	Because if I don't participate, my reputation will be affected badly.

SRQ-A is a self-report instrument developed within the self-determination theory paradigm that measures students' motivation by soliciting the reasons for students' engagement in school settings. There are four sets of questions in SRQ-A, including "*1. Why do I do my homework?*", "*2. Why do I work on my class work?*", "*3. Why do I try to answer hard questions in class*?" and "*4. Why do I try to do well in school*?" Each question is followed by eight similar items which list the possible reasons for their engagement in relation to the *task* and *reinforcement* dimensions in the learning settings. For example, the eight items in Question 1 are "*because I want the teacher to think I'm a good student*", "*because I'll get in trouble if I don't*", "*because it's fun*", "*because I will feel bad about myself if I don't do it*", "*because I want to understand the subject*", "*because that's what I'm supposed to do*", "*because I enjoy doing my homework*" and "*because it's important to me to do my homework*". The 32 items in SRQ-A comprise four motivation sub-scales (external regulation, introjection, identification and intrinsic motivation). Each respondent's score on each sub-scale can be calculated by averaging the item scores on the respective subscale, from very true (4) to not at all (1).

Table 1 lists three question stems and the 20 response items in CIPQ. The first two question stems and the associated eight response items are adopted from SRQ-A. To solicit responses specific to collaborative inquiry-based learning contexts, a new question stem (*why do I participate in project work?*) and 12 response items were developed, with four items on the inquiry aspect (*Item 10, 11, 14 & 16*) and the remaining eight items on the social aspect (*Item 9, 12, 13, 15, 17, 18, 19 & 20*) of the learning situations. Respondents are required to select their responses on a 7-point likert-scale, from 1 (strongly disagree), 4(neutral) to 7(strongly agree).

RESEARCH SETTING

For the purpose of establishing the scale structure and validity of CIPQ, the instrument was administrated to students who participated in the Learning Community Projects[1] (LCP) organized by the Centre for Information Technology in Education (CITE) at The University of Hong Kong. LCP is a set of design experiments on computer-supported collaborative learning (CSCL) using Knowledge Forum®[2] (KF). From July 2002 to May 2004, four rounds of collaborative inquiry-based projects were organized, including Peer Tutoring Project (PTP; Jul-Oct, 02), Assessment for Better Learning Project (ABL; Jun-Sept,03), Promoting Higher-order Thinking Through Knowledge Building Project (PTP; Oct-Dec, 03) and Go Up Stay High Project (GUSH; Mar-May, 04). In each of these four rounds, there were about 200 to 300 grade 9 to 12 student participants, coming from several secondary schools in Hong Kong. The students from the same class were organized to form groups varying in size from four to six to work on a study topic for about six to eight weeks, with their teachers as the facilitators. The topics of study for the projects were generally assigned by the teachers, in subject areas ranging from the sciences to humanities.

STRUCTURE OF MOTIVATION IN COLLABORATIVE INQUIRY-BASED LEARNING

Two rounds of the 24-item CIPQ (pre-PTP, n=269; post-PTP, n=235) were administered to the LCP participants. Based on the item statistics, four item responses were removed to form a reduced 20-item version of the CIPQ (Chow, 2003). Four rounds of this 20-item version was subsequently administered (post-ABL, n=173; pre-PHT, n=192; post-PHT, n=300 and post-GUSH, n=254). Investigations of the motivational structure began with an exploratory factor analysis using SPSS (SPSS, 1999) and followed by the construction of confirmatory factor analytic models with LISREL (Jöreskog & Sörbom, 1993). Exploratory factor analysis is a statistical procedure for exploring characteristic features among a set of variables for detecting their underlying latent factors (Byrne, 1998). It is widely recognized as a useful method in the early stages of empirical data analysis for examining uncertain links between variables and latent factors (Jöreskog & Sordom, 1993). With the information gathered from exploratory factor analysis as prior information, sequential confirmatory factor analysis was conducted. It involved more rigorous statistical techniques to construct measurement models for confirming or disproving hypothesized underlying latent variable structures (Byrne, 1998). To further ensure the robustness of the instrument, the models constructed for the two versions of CIPQ in the current study were each validated with an independent set of data.

A five-factor model was repeatedly founded according to the CIPQ responses collected from PTP, ABL, PHT and GUSH. To determine the statistical adequacy, each model was evaluated by a set of goodness of fit statistics: Root Mean Square Error of Approximation (RMSEA) developed by Steiger (1990), non-normed fit index (NNFI) developed by Bentler & Bonnett (1980) and comparative fix index (CFI) developed by Benlter (1990). It is generally suggested that a model with RMSEA lower than 0.1 and both NNFI and CFI being larger than 0.9 is taken as statistically well-accepted (Kelloway, 1998; Diamantopoulos & Siguaw, 2000).

[1] Details of these projects can be found at http://lcp.cite.hku.hk
[2] Details about Knowledge Forum® can be found at http://www.learninginmotion.com/products/kf/index.html

An examination of the goodness of fit statistics of the validated models in Table 2 reveals that the 20-items version offers a better statistical fitness than the 24-items CIPQ (e.g., from RMSEA=0.091 to RMSEA=0.070, 0.076 and 0.078).

Table 2 Goodness of Fit statistics of the Validated Five-Factor Models

Instrument & Data used	RMSEA	CFI	NNFI
24-item CIPQ:			
Pre-PTP (n=269), validated by post-PTP (n=235)	0.091	0.92	0.92
20-item CIPQ:			
Post-ABL (n=173),validated by pre-PHT (n=192)	0.070	0.94	0.94
Pre-PHT (n=192), validated by post-PHT (n=300)	0.076	0.94	0.94
Post-PHT (n=300), validated by post-Gush (n=254)	0.078	0.94	0.93

Table 3 lists the five latent factors and the associated response items in the final 20-items model. By examining the meanings of their respective items, the five factors were labelled as Project Work factor, Social Learning factor, Task factor, Reinforcement factor and Social Pressure factor. The Cronbach's Alphas which indicate the reliability among the items of the factors are also listed in Table 3. Indeed, controlling the length of the scale while maintaining a reasonable reliability are both critical in scale development. According to Loewenthal (2001), a scale with less than 10 items with its reliability above 0.6 is considered as well-designed. In this regard, the five scales of CIPQ, each comprising of four items, were found be reliable across the different sets of data collected.

Table 3 The Latent Factors in the Five-Factor Model (20-item Version CIPQ)

Factor	Response Item	Cronbach's Alpha
Task Factor	Because that's what I'm supposed to do.	Post-ABL (n=173): 0.748
	Because I enjoy doing my classwork.	Pre-PHT (n=192): 0.638
	Because I want to learn new things.	Post-PHT (n=300): 0.681
	Because I enjoy doing my school work well.	Post-GUSH (n=254): 0.694
Reinforcement Factor	Because I will be scolded be my parents or teachers if I don't do well.	Post-ABL (n=173): 0.674 Pre-PHT (n=192): 0.657
	Because I might get a reward if I do well.	Post-PHT (n=300): 0.632
	Because I want the teacher to think I'm a good student.	Post-GUSH (n=254): 0.673
	Because I'll be ashamed of myself if it didn't get done.	
Project Work Factor	I participate in project work because it's fun.	Post-ABL (n=173): 0.828
	Because it's important to me to do project work.	Pre-PHT (n=192): 0.862
	Because participating in project work can help my academic learning.	Post-PHT (n=300):0.808 Post-GUSH (n=254): 0.855
	Because comparing with learning by doing homework, it is more effective to learn by doing project work.	
Social Learning Factor	Because I like to work with my classmates in group activities.	Post-ABL (n=173): 0.853
	Because working in group (compare with working individually) allow me to tackle more complex project topics.	Pre-PHT (n=192): 0.891 Post-PHT (n=300):0.807
	Because there are many chances for discussion and sharing ideas by working in groups.	Post-GUSH (n=254): 0.848
	Because learning in group allows me to have more courage to investigate more complex topics.	
Social Pressure Factor	Because if I don't participate, the friendship between my friends and I will be affected badly.	Post-ABL (n=173): 0.792 Pre-PHT (n=192): 0.873
	Because if I don't participate, my groupmates will blame me.	Post-PHT (n=300): 0.803
	Because I don't want to be perceived as a burden of my groupmates.	Post-GUSH (n=254): 0.760
	Because if I don't participate, my reputation will be affected badly.	

As can be seen from Table 3, the adopted items from SRQ-A were all clearly clustered together under the Task and Reinforcement factors. This outcome aligns with the classic intrinsic-extrinsic perspective which identifies both task and reinforcement as important dimensions in learners' motivational structure. However, the emergence of the other three factors shed light on changes in learners' motivation structure when learning takes place in collaborative inquiry-based settings. The Project Work factor was constituted by items pertaining to positive values associated with the task nature of project work and could be understood as an extension of the task dimension. The differentiation of the Task and Project Work factors indicates that students considered project work as activities distinct from general school work, possibly reflecting their identification of the inquiry nature of project work. On the other hand, the Social learning and Social Pressure factors indicate that the social aspect of the new learning contexts has an impact on learning motivation as well.

CIPQ MOTIVATIONAL SCORES & PROJECT ENGAGEMENT: EMPIRICAL EXPLORATIONS

Caution on the validity of self-report instruments in assessing motivation has been raised by many researchers (Brown, 1988; Boekaerts, 2001). The validity of the instruments lies with their applicability in understanding and explaining learners' behavior in the learning process. In this study, the five motivational factor scores of students were analyzed in relation to their observable learning behaviors in two ways: the quality and quantity of their engagement in the computer-supported collaborative learning tasks in LCP.

CIPQ Factor Scores and the Quality of Engagement

PTP was a reward scheme[3] in which students had to work in groups to complete an inquiry-based project over the summer holiday. The winners of the nine awards (these include both group and individual awards) were selected based on a list of criteria associating to various aspects of knowledge building (Scardamalia & Bereiter, 1999), including the social aspects (i.e., Best Peer Tutor, Most Supportive Collaborator), the quality of inquiry work of students (i.e., Best Research Award, Most Innovative Award, Most Reflective Journal Award) and good uses of KF functions (i.e., Best Use of KF Functions to Support Collaborative Knowledge Building Award, Best Use of Scaffold to Support Critical Thinking Award, Best Design of Views and Database Structures in KF, Best Use of KF for Scholarly Communication Award). The award winners were therefore the students who engaged in the projects with a higher quality of learning outcome than their counterparts.

It was hypothesized that the learners' motivation was highly associated with the quality of their learning outcome. Therefore, a t-test was done to check the differences on the five motivation scores between the PTP award winners (n=64) and their counterparts (n=132). The analysis results found that both before and after the project, the award winners scored significantly higher in the Project Work factor, Social Learning factor and Task factor than their counterparts by 0.274 ($p \leqq 0.05$) in the pre-project data and this difference was even larger in the post-project data, which became 0.367 ($p \leqq 0.005$). This suggested a positive connection between the motivational scores for the Project Work, Social Learning and Task factors and the quality of students' project engagement.

CIPQ Factor Scores and the frequency of engagement

Another indicator of the extent of a learner's engagement in the computer-supported collaborative learning task is the frequency of online reading and writing activities. The Analytical Tool Kit (ATK) is a peripheral software of KF designed to provide data for the monitoring of the online activities within the platform, for example, the number of notes created and scaffold supports used by a participant (Burtis, 1998). The ATK information of the PHT participants (n=300) was used for investigating the correlations between their CIPQ motivational scores and their frequency of engagement on KF.

Table 4: Correlation Matrix of the 5 Motivational Scores and usages of KF (n=300)

Engagement indicators	Project Work	Social Learning	Task	Reinforcement	Social Pressure
Notes created	.170**	.150**	.148*	-.030	.010
Notes read	.179**	.125*	.196**	-.019	-.022
References in notes	.182**	.193**	.159**	-.008	-.054
Scaffold supports used	.210**	.247**	.248**	-.072	-.073

** p< 0.01, *p<0.05

Table 4 lists the correlations between the five motivational scores and the engagement of the PHT participants as reflected by the four engagement indicators provided by ATK: the number of notes created, the number of notes read, the number of references and scaffolds used in the notes created by each participant. The

[3] Details about the PTP award scheme can be found at http://lcp.cite.hku.hk/Activities/PTP/Awards/

Project Work factor, Social Learning factor and Task factor were all found to show significant positive correlation with all of the four engagement indicators. This finding provides consistent triangulation with the significant correlation found between the Project Work, Social learning and Task factors with the quality indicators of project engagement reported earlier.

CONCLUSION

This paper argues that as learning in schools change from the traditional model of individual attainment of well-specified learning goals to collaborative inquiry-based formats, motivational research should seek to develop new motivational models and instruments which are more attuned to capture the newly introduced inquiry and social aspects of the new learning contexts. The current study has developed an instrument that measures motivation in collaborative inquiry-oriented learning contexts, which yielded five motivational factors, including the Task and Reinforcement factors generally found in the established motivation instruments, as well as three new factors, the Project Work, Social Learning and Social Pressure factors. The emergence of these new factors reveals the new dimensions in learning motivation brought about by the changes in learning organization.

Repeated administrations of CIPQ to independent student groups have yielded statistics that indicate strong robustness of the instrument. The validity of the five-factor model and the potential utility of the CIPQ motivational scores were demonstrated by the empirical relationships found between these scores to both the quality and frequency indicators of the learners' engagement in the LCP projects. Although CIPQ and its five motivational factor model was developed along with the data collected from different computer-supported projects, as the respective items of each factor did not necessarily refer to any computer-supported settings, the researchers would understand CIPQ as a generic instrument applicable in either computer-using or non-computer-using collaborative inquiry-based situations.

Based on the findings of this study, it can be concluded that CIPQ is quite a valid self-report instrument in understanding motivation in the new learning contexts. The researchers see its potential in generating quantifiable information (i.e., the factor scores) for measuring the levels of respondents' motivation regarding the five latent factors. Nevertheless, the reported study is only the beginning of a larger project. To further investigate and validate what actually the five subscales are assessing, the next phase of the study will conduct analysis on the factor scores in relation to the interaction and learning processes of the LCP participants, for example, their self-regulated learning behaviour. In the long run, it is hoped that this instrument will be found to be useful for investigations aimed to further our understanding of learning motivation in CSCL contexts. For example, how does an individual's motivation affect his/her behavior in groups? How would individuals with different motivational score profiles interact with each other when they work in the same group? How does motivation relate to the inquiry process of the learners, such as the depth of idea interaction, their self-regulated behaviour and affective sharing patterns?

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Analyzing the Quality of Argumentation Supported by Personally-Seeded Discussions

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Abstract. Several researchers have shown that student participation in discourse paralleling that of scientific communities is critical to successful science education. This study focuses on supporting scientific argumentation in the classroom through a personally-seeded online discussion system. Students use an online interface to build principles to describe data they have collected. These principles become the seed comments for the online discussions. The software sorts students into discussion groups with students who have built different principles so that each discussion group can consider and critique multiple perspectives. We outline a methodology for (a) coding the individual comments in terms of epistemic operation, grounds, and content normativity and (b) parsing and assessing overall argumentation structure of the oppositional episodes. This study therefore contributes to the research literature both in terms of scaffolding and assessing student argumentation in online asynchronous forums.

Keywords: Education, Conversation Analysis, Argumentation, Discussions, Secondary School

INTRODUCTION

Research shows that students' participation in discourse paralleling that of scientific communities is critical to successful science education (e.g., Lemke, 1990; Rosebery, Warren, & Conant, 1992; Schauble, Glaser, Duschl, Schulze, & John, 1995). Argumentation is a genre of discourse crucial to the practice of science (Driver, Newton, & Osborne, 2000; Kuhn, 1993; Lemke 1990; Siegel, 1995; Toulmin, 1958), and much of science involves dialectical and rhetorical argumentation (Latour & Woolgar, 1986; Longino, 1994). This study focuses both on scaffolding and assessing scientific argumentation in the classroom through a customized online discussion system.

Computer-based supports for argumentation: Personally-seeded discussions

Structured environments have been built to support scientific argumentation, discourse, and knowledge refinement. Some of these environments like Collaboratory Notebook (Edelson, Pea, & Gomez, 1996), CaMILE (Guzdial, Turns, Rappin, & Carlson, 1995), and Knowledge Forum/CSILE (Scardamalia, Bereiter, & Lamon, 1994) are learning environments unto themselves that focus heavily on knowledge collection and building. Others, like SpeakEasy (Hoadley, Hsi, & Berman, 1995), Sensemaker (Bell, 1997), and the BGUILE data reporting section (Tabak, Smith, Sandoval, & Reiser, 1996), are part of larger inquiry environments. In addition to these specialized environments, basic online threaded asynchronous forums in which discussions are held have also been shown to be effective in supporting classroom-based discourse (Collison, Elbaum, Haavind, & Tinker, 2000; Salmon, 2000).

Whereas the online environments detailed above focus either on sharing information or on preparing arguments for presentation, our personally-seeded discussion system focuses specifically on engineering and supporting scientific argumentation within classroom discourse. Personally-seeded discussions (a) help students synthesize a principle to describe data that they have collected or found in light of other evidence from their classroom and homes, (b) create groups of students who have created different principles to describe the data, (c) facilitate online discourse among the students where they critique each other's principles in light of the evidence and work toward consensus through scientific argumentation based on the evidence, and (d) provide students with models of productive scientific argumentation.

The personally-seeded discussion system analyzed in this study is embedded in an online inquiry project. After collecting data, students create principles to describe patterns in the data. Research on students' initial conceptions about heat and temperature (Clark, 2000, 2001; Lewis, 1996; Linn & Hsi, 2000) and earlier thermodynamics curriculum development (Lewis, Stern, & Linn, 1993) form the foundation of a new Web-based principle-builder interface that allows students to construct scientific principles from a set of predefined phrases and elements (Figure 1). After students create their principles, the project software places the students in electronic discussion groups with students who have constructed different explanatory principles. A screenshot of a portion of an asynchronous discussion within the thermodynamics project from this study is included in Figure 2.

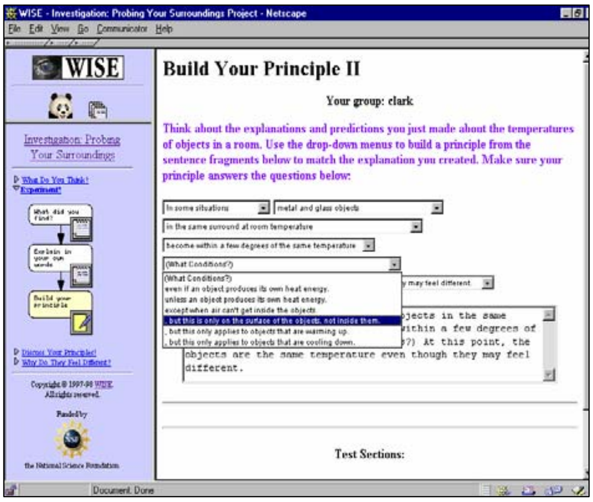

Figure 1. Students use the principle-builder to construct scientific principles that become initial discussion comments

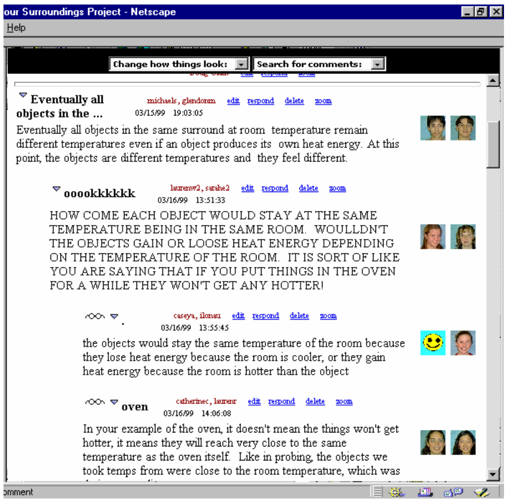

Figure 2. An example of a personally-seeded discussion

The student-constructed principles appear as the seed comments in the discussions. The discussions develop around the different perspectives represented in the seed comments, ideally through a process of comparison, clarification, and justification. As part of this process, the students are required to support their assertions and claims with evidence from their labs and other experiences. This process attempts to elicit self-explanation by helping students focus other students' attention on possible inconsistencies in their explanations and on reasoning, plausibility, completeness, and other attributes of "good explanations." In these discussions, all students and their ideas become critical resources with the common goal of refining individual student ideas.

Analysis of student argumentation

To make judgments about argumentation quality, researchers over the last decade have developed several different methods to identify the essential features of an argument. These methods have been used to examine the structure of student arguments in small group conversations (Forman, Larreamendy-Joerns, Stein, & Brown, 1998; Kelly, Druker, & Chen, 1998; Resnick, Salmon, Zeitz, Wathen, & Holowchak, 1993) and in writing (Bell & Linn, 2000; Kelly & Takao, 2002). To date, most of these investigations of student discourse have relied heavily on Toulmin's (1958) model for argument structure in one way or another. In these studies, emphasis is placed on the identification of the structural features of arguments (e. g., claims, data, warrants, backings, and qualifiers) and the process of argumentation, especially in terms of how students provide warrants for claims. Such approaches seek to identify the absence or presence of the components of argument and use this information to assess argumentation quality. Structural analyses of student arguments contribute to our understanding of how students assimilate the desired practices of argumentation (Driver, Newton, & Osborne, 2000) and provide a great deal of information about the form and type of reasoning that students use when they construct arguments based on their everyday experiences (Simon, Osborne, & Erduran, 2003).

Although structural analyses of student argumentation is important in understanding students' reasoning when they construct arguments, these analyses should also include judgments of the quality of arguments in terms conceptual adequacy (Sandoval, 2003; Schwarz, Neuman, Gil, & Iiya, 2003; Zohar & Nemet, 2002). For instance, Zohar and Nemet (2002) found that although a majority of students are able to construct simple scientific arguments in the context of a unit on genetics, only a small minority included correct, specific scientific knowledge in their arguments. In our own research, we have found that students often include grounds which incorporate real world examples or data from prior labs when making claims or rebuttals. For example:

> Why do you disagree? Remember when we did the potato lab? Even the things that were well insulated would eventually reach room temperature. Also remember how circuits use copper wire because we know that copper is a good conductor! Obviously the good conductor would reach room temperature first as opposed to bad conductors.

From the perspective of argumentation structure, a rebuttal like this is excellent in its use of data and warrants. However, even though the students raise important data from a prior lab activity, they confuse electrical and thermal conductivity in their real-world example. Normative conceptual content unfortunately does not always accompany desirable argumentation structure. As science educators strive to help students develop the cognitive skills required to construct, evaluate and defend scientific arguments, analytic methods must be developed to assess the quality of argumentation structure as well as the quality of the scientific content.

RESEARCH QUESTIONS

In addition to developing our personally-seeded discussion environment, we are concurrently developing a method to assess student argumentation based on the epistemic operation of the comments that students make, the grounds students use, and the conceptual quality of their arguments. This current study asks three questions: (1) What is the nature of the arguments constructed by students in our personally-seeded environment in terms of epistemic operation, grounds, and conceptual quality? (2) Is there a relationship between the structural quality of the episode in which a comment occurs and the quality of the comment's grounds or content? (3) How robust and reliable is this new coding method?

METHODS

This study incorporates and augments the coding schemes developed by several researchers to analyze the structure of student argumentation (e. g., Jimenez-Aleixandre, Rodrigues, & Duschl, 2000; Simon, Erduran, & Osborne, 2002). We first outline the methods we used to code each individual comment in terms of epistemic operation, quality of grounds, and quality of subject matter. Following the coding discussion for the individual comments, we outline our method of parsing and scoring the oppositional episodes within which the comments take place.

Participants

Eight randomly chosen online discussions involving a total of 84 students are analyzed from four classes of eighth grade students who completed the project during one semester under the supervision of an experienced teacher who has worked extensively with the researchers. The public school is located in a diverse city and has an even distribution of boys and girls. The classes are typical 8th grade physical science classes, labeled neither "honors" nor "remedial." Each online discussion involves approximately five pairs of students. Students work on the project in pairs over the course of six class periods (five hours in total). The discussions begin at the start of the fourth class period and extend through the end of the fifth class period). To represent multiple perspectives, the software assigns student pairs to discussions with students who have created different principles, as discussed above.

Coding Individual Comments

Students make a total of 334 comments in the 8 discussions. All comments are coded in light of the parent comment to which they reply, which means that the comments are coded in context rather than as individual statements.

Coding the epistemic operation of a comment

We code the epistemic operation of a comment in terms of the comment's role (or intended role) in a co-constructed dialogic argument. We code each comment in relation to the actual parent comment to which it responds to avoid ambiguity in terms of references within a comment. The coding scheme is outlined in Table 1 below. These codes take into account comments that are part of the actual argumentation, meta-organizational comments within the discussion that are not truly part of the argumentation but that help organize the interaction, and the occasional off-task interactions.

Table 1. Coding scheme for Epistemic operation of individual comments.

Claim (CM): A hypothetical statement or a seed-comment principle made by a group of students.
Counter-Claim (CC): A hypothetical statement or a principle made by a group of students that is different from and (does not attack in any way) the seed claim or parent comment made by another group. This code is only assigned when a comment does not focus on any aspect of the thesis of the comment it replies to; instead it offers an entirely new interpretation of the phenomena.
Rebuttal Against Grounds (RAG): An attack on, or disagreement with, the grounds (evidence, explanations, qualifiers, or backing) used by another group to support or justify their comment. Comments in this category include: (1) using a rhetorical question as a way to question the validity of the grounds used by the other group, (2) statements that attempts to limit the conditions that evidence can be used, (3) a reinterpretation of the grounds used by the other group, (4) disagreement with the way empirical data was gathered, (5) disagreement with the way data is used, or (6) disagreement with the accuracy of the empirical data.
Rebuttal Against Thesis (RAT): An attack on or disagreement with the thesis (or a specific part of the thesis) of another group's comment (claim or rebuttal) that does not attack the support (grounds) used by the other group. This category includes: (1) using a rhetorical question as a way to question the validity of the claim used by the other group, (2) asking a specific question about some portion of a comment where the intent is not to clarify the meaning but rather to question validity or accuracy, (3) correcting a specific aspect of another groups claim or rebuttal but not the grounds, (3) comments that express disagreement with the thesis of another group's comment and then offer a new claim
Support of a Comment (SC): A statement used to support the truth or accuracy of the previous claim or rebuttal. This category includes statements that (1) voice agreement with a comment (2) rewords the previous comment (3) adds additional grounds in support or (4) expands the comment.
Query about Meaning (QUM): A comment that asks for clarification of an earlier comments (e.g., "What do you mean when you say...?" or "I don't understand what you are saying?"). These comments question the meaning of a statement rather than the accuracy of the statement. Therefore, rhetorical questions used as a way to question the validity of a claim or grounds are not included in this category.
Clarification of Meaning (CLM): A comment made by a group of students to clarify (restate in a new way) a previous comment. The purpose of these comments is to clarify the meaning of a statement in response to a query (about meaning) rather the supporting the accuracy of a statement
Clarification in response to a Rebuttal (CLR): This code is assigned to comments that are used to strengthen a position (in terms of accuracy or validity) in response to a rebuttal without attacking the rebuttal or grounds made by another group.
Change of Claim (CH): A comment made by a group of students that indicates that (1) they have changed their original claim or (2) changed their viewpoint, or (3) have made a concession in response to comments (claims or rebuttals) made by another.
Organization of Participants (OP): A comment that (1) reminds other participants to participate, (2) asks others for feedback, (3) has a metacognitive aspect (e. g. "Do we all agree?"), (4) attempts to change the way someone else in the discussion is participating.
Off Task (OT): Comments that are not about the topic (e.g., "Nice haircut, John!").

Coding the grounds of a comment

Once these base codes are assigned to characterize epistemic operation, the grounds are coded using the flow chart in Figure 3. Grounds include data, warrants, and backings (e.g., "The metal chair felt different but it was room temperature in our experiment"). Erduran et al. (Erduran, Osborne, & Simon, 2004; Simon et al., 2003) collapsed this category because of pragmatic challenges in reliably differentiating data, warrants, and backings in student transcripts. Rather than attempting to differentiate between data warrants and backing we classified the grounds of a comment as either: no grounds (level 0), using an explanation as grounds (level 1), using evidence as grounds (level 2), and coordinating multiple pieces of evidence or multiple connections between ideas in the evidence (level 3).

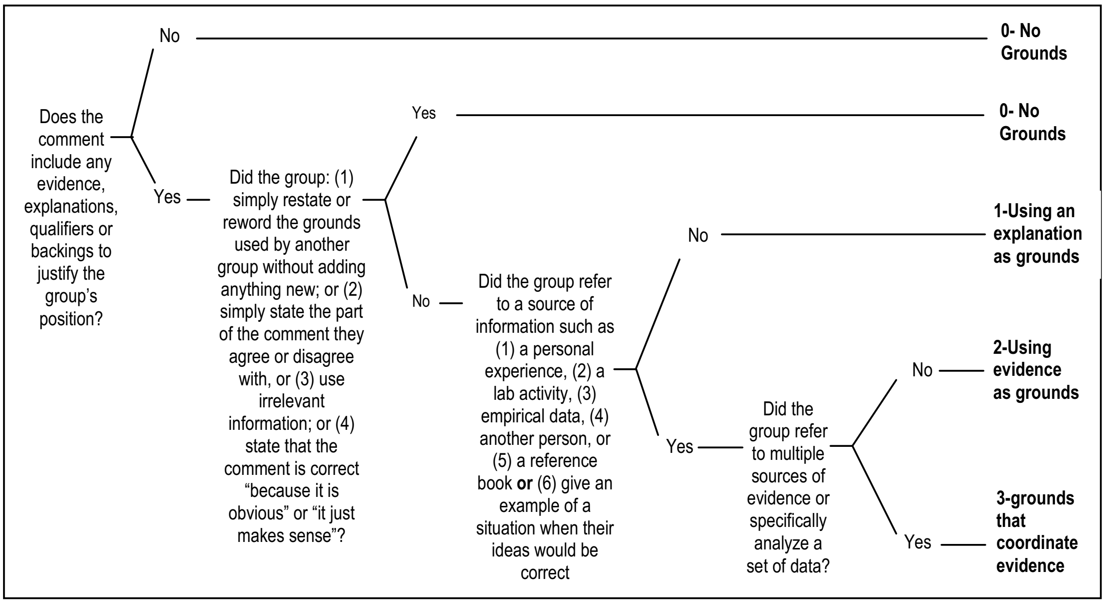

Figure 3. Flow chart for coding the grounds of an individual comment

Coding the conceptual quality of a comment

Finally, the overall conceptual quality of the comment is rated as either: non-normative (level 0), transitional (level 1), normative (level 2), or nuanced (level 3) after the structure of the groups' comment has been characterized. The coding of conceptual quality involves a coding key of the facets of students' statements similar to Jim Minstrell's facet analysis that was developed for thermodynamics as part of earlier work (Clark, 2000; Clark submitted). In coding a comment, we first determine how many non-normative, transitional, and normative facet are included as part of the entire comment using the facet tables developed through our earlier work (Clark, 2003). These facet tables are not included here due to space restrictions, but may be accessed online through the URL in the reference section. These papers also include further information about coding content facets as non-normative, transitional, normative, and nuanced. After coding the individual facets of a comment, the overall conceptual quality of a comment is determined using the flow chart in Figure 4. The flow chart assigns an overall conceptual quality score based on the frequency of non-normative, transitional, and normative facets found within the entire comment. If the comment does not make sense or the reader can not determine what the authors of a comment are trying to say, the comment is scored as non-normative (0).

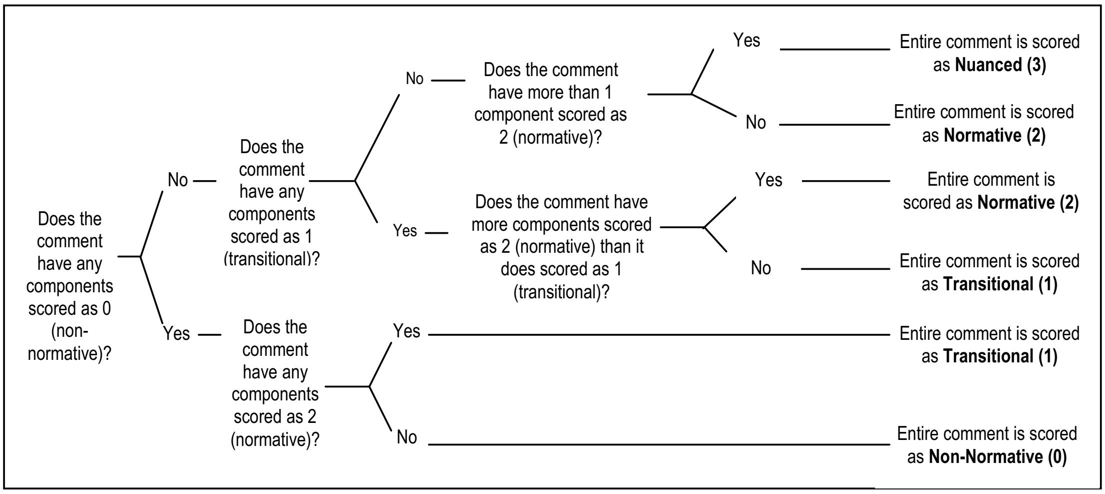

Figure 4. Flow chart for coding the conceptual normativity of an individual comment based on its facets

Parsing and Scoring Oppositional Episodes

After coding the individual comments, we then code the larger episodes within which the comments occur. In particular, we are interested in oppositional episodes. One challenge involves creating an objective parsing scheme to define episodes. These discussions are threaded and asynchronous. That means that the students may respond to any contribution in their discussion at any time. As is typical in asynchronous threaded forums, responses are placed by the software underneath the parent comment and indented. A fragment of a typical discussion generated from one initial seed claim is outlined in Figure 5. The current study considers the discussion fragment defined by the 2nd level comments (including its parent claim and its children) to be the unit of analysis (i.e., one episode). In Figure 5, there are therefore two episodes defined by 1.1 and 1.2. The 1.1 episode includes 1 and 1.1 only, while the 1.2 episode includes 1, 1.2, and 1.2.1. Each of these episodes is analyzed as a potential oppositional episode. In the Figure 5 example, the episode defined by 1.2 contains opposition while the 1.1 episode does not. Within the actual discussions, a time stamp accompanies each comment to establish the precise time of contribution.

Using the coding schemes for the individual comments, Group 1's comment is a *Claim* with transitional content and no grounds. (Claims created through the principal-maker interface are considered not to include grounds because the student could not add them.) Group 2's comment is *Support* with transitional content and level 2 grounds because they cite the lab results. The episode defined by Comment 1.1 contains only these two comments. This episode contains no opposition and is therefore coded as a non-oppositional episode.

The other episode in the example is defined by Comment 1.2 and includes 1, 1.2, and 1.21. It includes opposition and so is coded as an oppositional episode. Group 3's comment in is coded as a *Rebuttal Against Thesis* to the "Immediately" part of Group 1's initial claim. Group 3 supports its rebuttal with an explanation about conductivity affecting the rate of temperature change but no evidence (grounds level 1). The conceptual quality of Group 3's comment is coded as being *nuanced* because they claim that the two objects will reach thermal equilibrium but the rate will be influenced by an object's conductivity.

Comment:1 *Epistemic*: Claim *Grounds*: Level 0 *Conceptual Quality*: Transitional	**Group 1** *(This initial statement by a student pair (group 1) is the principle they created to describe their lab data. The principles created then became the seed comments in an online threaded discussion.)* Immediately all objects in the same surround at room temperature become within a few degrees of the same temperature unless an object produces its own heat energy. At this point the objects are within a few degrees even though they may feel different.
Comment: 1.1 *Epistemic*: Support *Grounds*: Level 2 *Conceptual Quality*: Transitional	**Group 2** *(response to Group 1)* We agree with this because in the lab we observed that almost all objects were around the same temperature.
Comment: 1.2 *Epistemic*: Rebuttal against claim *Grounds*: Level 1 *Conceptual Quality*: Nuanced	**Group 3** *(response to Group 1)* How do you know that the temperature changes immediately? Wouldn't it change at different rates depending on how good a conductor the object is? Couldn't it reach the temperature at a slower or faster rate, although it will eventually reach the same or close to the same temperature of the room?
Comment: 1.21 *Epistemic*: Support *Grounds*: Level 1 *Conceptual Quality*: Transitional	**Group 4** *(response to Group 3)* You're right!!! The materials' ability to conduct heat will determine how fast it will heat up. Just like with electricity.

Figure 5: Coding of the comments associated with one seed claim

Once individual codes are assigned, overall quality within the oppositional episode can then be analyzed using Table 2 below which we created based on a structural hierarchy developed by Erduran, Osborne, and Simon (Erduran et al., 2004; Simon et al., 2002). After assigning the structural quality of each oppositional episode, our current study then analyzes correlations between the structural quality of the episode in which a comment occurs and the quality of the content and grounds within that comment.

Table 2: Assigning overall structural argumentation score to an episode.

Level 5	Argumentation that displays an extended argument that includes multiple rebuttals attacking claims and at least one rebuttal that attacks the grounds used to support a claim
Level 4	Argumentation consists of an extended argument that includes multiple rebuttals that attack claims however there are no rebuttals against the grounds used to support a comment
Level 3	Argumentation has arguments with a series of claims or counter-claims that include grounds with only a single rebuttal
Level 2	Argumentation has arguments with claims or counter-claims with grounds but no rebuttals
Level 1	Argumentation consists of arguments that are simple claim versus counter-claim. There are no grounds or rebuttals included.

RESULTS AND DISCUSSION

We recently completed the coding of the comments and episodes, and we now present the initial analysis of the data. We are currently employing more sophisticated statistical techniques to study the interconnections between structural quality of the argumentation in an episode and the epistemic operation, grounds, and conceptual quality of the constituent comments in a more nuanced manner, and we will discuss this analysis at the conference.

The nature of the arguments constructed by students in the PSD environment in terms of context specific content and students' epistemological ideas about argumentation

The comments from the eight discussions are organized by epistemic operation (Figure 6), type of grounds included (Figure 7), and conceptual quality score (Figure 8). The eight discussions involve a total of 334 comments. All 334 comments received an "epistemic operation" code, and 269 of the 334 comments received a code for the type of grounds included and conceptual quality (because certain epistemic types, such as *Organization of Participation*, *Query about Meaning*, and *Off Task*, are not coded for grounds and conceptual quality.) This analysis indicates that students tend to challenge the thesis of a comment (*Rebuttal Against Thesis: 92*) rather than challenge the grounds used by another group (*Rebuttal Against Grounds: 37*). Support of a Comment (69) is the next most common epistemic operation, followed by *Off Task* comments (42) and *Claims* (36). *Query about Meaning* (17) and *Organization of Participation* (7) were less frequent, but played important roles in moving the discussion forward. Out of the 36 initial *Claims*, we do see 10 *Change of Claims*, which suggests that students are willing to consider revising their ideas based on the discussions.

In terms of providing grounds, similar to other research that suggests that students do not usually provide warrants for their claims unless they are challenged (Kelly et al., 1998), students only supported their comments with grounds approximately 51% of the time. When grounds are included as part of a statement, students rely on an unsubstantiated explanation (a causal mechanisms for why a comment is true) rather than including evidence (facts from a source) to support their ideas 47% of the time. In terms of conceptual quality, student comments are spread fairly evenly in terms of non-normative (29%), transitional (28%), and normative (39%) conceptual quality. Only 4% of the comments are of nuanced conceptual quality.

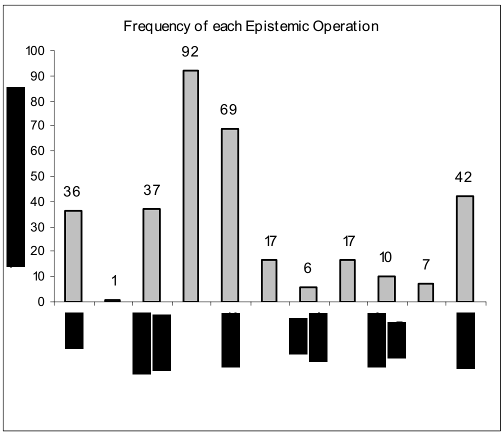

Figure 6: Frequency of comments in terms epistemic operation

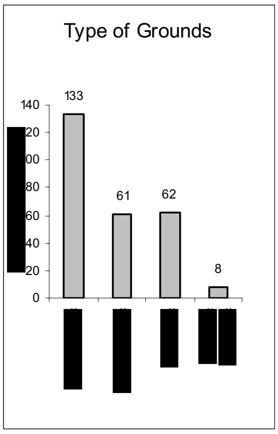

Figure 7: Frequency of the of different types of grounds included in a comment

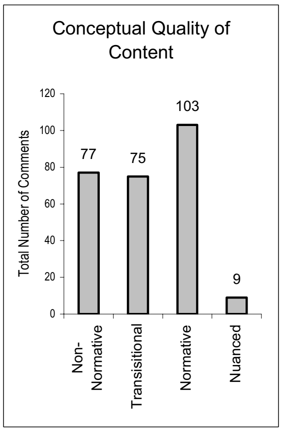

Figure 8: Frequency of comments in terms of conceptual quality

The relationship between the structural quality of the episode in which a comment occurs and the quality of the comment's grounds and content

The discussions analyzed as part of this study include 126 total episodes involving 334 student comments. Of these episodes, 66 qualify as oppositional episodes and 60 do not. Most non-oppositional episodes tend to be very short (mean number of comments = 2.03) and students do not usually include grounds in order to support their comments (78% of the comments). The conceptual quality of the comments in these episodes tends to be transitional (60% of the comments) or non-normative (21% of the comments) in nature (see Figure 9 and 10). In summary, the non-oppositional episodes tend to be relatively unsophisticated in terms of scientific discourse structures. Students tend to accept what is written in the claim and move onward.

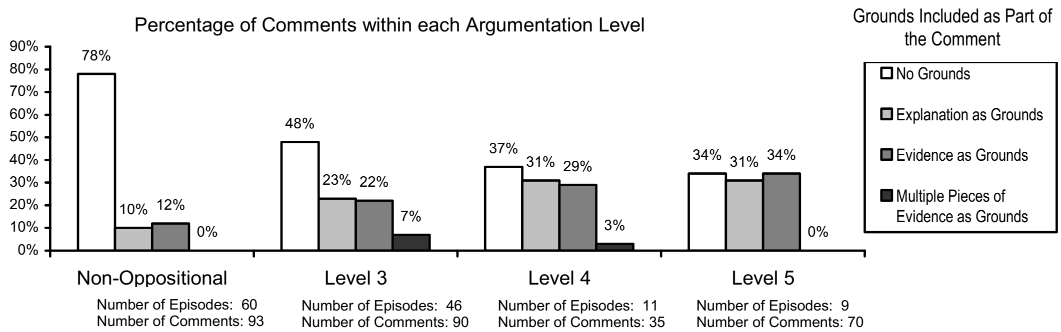

Figure 9: Percentage of the total comments within an argumentation level in terms the type of grounds included

On the other hand, oppositional episodes are longer. For example, the 9 episodes involving multiple sequential rebuttals (level 5) have a mean number of comments of 8.11. This much longer average is heavily weighted by the single longest episode, which spanned 26 comments. Overall, the oppositional episodes include a greater percentage of comments that include grounds (see Figure 9). In level 3 episodes, 53% of the comments include grounds; in the level 4 episodes, 63% of the comments include grounds, and in the level 5 episodes 65% of the comments included grounds. Overall, comments in non-oppositional episodes had a mean grounds score of .38 (SD = .75), comments in the level 3 argumentation episodes had a mean score of .88 (SD = .98), comments in the level 4 argumentation episodes had a mean score of .97 (SD = .89), and comments in level 5 episodes had a mean score of 1.00 (SD = .83). A one way analysis of variance (ANOVA) indicates that these differences in the grounds included by the students are statistically significant, $F(3) = 7.284$, $p < 0.001$. These results suggest that in terms of structure, students are able to construct structurally sophisticated arguments.

Within the personally-seeded online discussion forums, students tend to support their statements by including relevant grounds.

In terms of conceptual quality, we also see a difference between oppositional and non-oppositional episodes (Figure 10). In level 3 episodes 42% of the comments coded for conceptual quality were scored as either normative or nuanced. In level 4 episodes the percentage rose to 49%, and in level 5 episodes 61% of the comments were either normative or nuanced. In addition, the percentage of transitional comments differed between non-oppositional episodes (60%), level 3 episodes (22%), level 4 episodes (14%), and level 5 episodes (13%). An additional analysis is underway in order to determine if persuasive students are able to lead other students to more normative understanding (or astray with non-normative grounds).

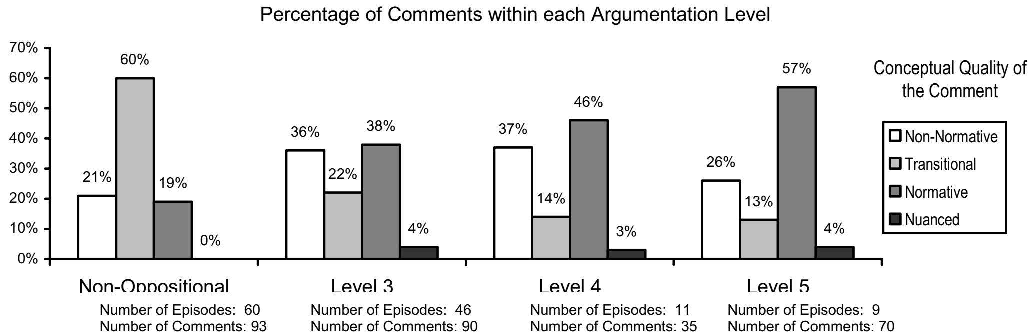

Figure 10: Percentage of the total comments within an argumentation level in terms of conceptual quality

Appropriateness and Reliability of the Coding Methods Developed and Presented

From a methodological standpoint, the practice of defining episodes based on the second-level comments seems appropriate given the average number of comments and the average depth of comment chains within the episodes in this study. The difference between mean number and mean depth is about 0.1 for non-oppositional episodes and oppositional episodes of level 3 or less. The difference for level 4 arguments is 0.2. These small differences between depth (length of longest chain in episode) and number of comments (total comments in episode) suggest that episodes tend to be linear rather than branched. This linear quality suggests that the current study's parsing scheme seldom combines significantly branched discussions as a single episode. Only the level 5 episodes approach a grey area, where the mean number of comments is 8.11 and the mean depth is 4.33 for the 18 episodes. One of these episodes is unusually large in comparison to the others, containing 26 comments on its own and a depth of 7 with multiple branches. It might be more appropriate to subdivide episodes of this size into multiple episodes representing each of the substantial branches within the large episode. Further analysis of extended episodes will be required to resolve this particular issue. Overall, however, this issue applied to only one episode out of 122 and the parsing method for defining discourse episodes proved appropriate for the vast majority of the episodes.

In order to establish the inter-rater reliability of the coding scheme, the eight discussions were independently coded by the two authors and compared. In spite of the complexity of the proposed coding scheme, inter-rater reliability using this coding system is high. In terms of epistemic operation codes, inter-rater reliability was initially 93%. The largest category of difference between the two coders involved distinguishing off-task comments versus supportive comments. By refining that definition in the coding scheme to include comments that thanked the parent comment's authors for providing support as *Support* rather than *Off Task*, inter-rater reliability climbed to 94%. The remaining 6% of differences were resolved through discussion. This remaining variance between coders seems relatively inevitable but well within an acceptable range.

The initial inter-rater reliability for the coding of grounds was 81%. The largest category of disagreement involved several instances where one author assigned the "explanation" code where the other author assigned the "evidence" code. By refining the evidence definition to include hypothetical examples, the inter-rater reliability climbed to 92%. The next largest category of difference involved one author assigning a "grounds" code where the other author assigned the "no grounds" code. To address the "grounds" versus "no grounds" issue, we revised our definitions to clarify that restating grounds previously included in the episode does not qualify as adding grounds to the argument, this resulted in an increase in inter-rater reliability to 95%. The remaining differences were resolved through discussion. Similar to other studies, we believe that the remaining 5% of variance between coders about the type (or presence) of grounds is acceptable, given the difficulties frequently cited in the literature in terms of the problematic nature of coding grounds. The coding scheme for the individual comments therefore appears to be highly reliable for trained coders in spite of its complexity. The coding of the individual comments draws on the work of many theorists. It is our hope that this coding scheme will continue to evolve and provide a tool for other researchers interested in the interplay of epistemic operation, grounds, and content.

In terms of scoring of the oppositional episodes, we developed our hierarchy of argumentation structure based on work by Erduran, Osborne, and Simon, but our coding scheme and hierarchy diverges from theirs in some important respects. From their perspective, only arguments that rebut the grounds of another person's argument can undermine the beliefs of that individual. In other words, oppositional episodes that do not rebut the grounds have no potential to change the thinking of the participants because the basis of each participant's beliefs rests on the grounds used as justification. This definition of a rebuttal seems appropriate for debates steeped in social values (e.g., the "socio-scientific" debates in Erduran et al's curriculum about whether zoos are good or bad). Erduran et al. define socio-scientific debates based on Monk (1997) as debates "examining and reforming social practices in the light of scientific evidence available through the press and other media." In socio-scientific debates, attacking a grounded claim (e.g., "zoos are good because people can see the animals and want to protect them") with a grounded reply (e.g., "zoos are bad because the animals are unhappy") is often a counter claim rather than a rebuttal. The attack presents another perspective but does not disqualify the initial claim and therefore fits with Erduran et al.'s coding definition that only comments that attack grounds can be coded as rebuttals.

Our study focuses on debates that Erduran et al. would term "scientific" that require empirical argumentation concerning the concept of thermal equilibrium. We define two types of rebuttals: (a) *Rebuttal Against Grounds* which attack the grounds supporting the parent comment's claim and (b) *Rebuttal Against Thesis* which directly rebut the claim of the parent comment. This definition is appropriate in an empirical context because grounds can be provided to fully refute the original claim. For example, a claim that "objects stay different temperatures even if you leave them out on the table for a long time because I've felt them and they feel different" can be rebutted by saying that "the objects actually become the same temperature like when we did the lab and the temperatures of the wood table and the bottle of soda both became 23 degrees after a long time" or by saying that "the objects only feel different even though they are the same temperature because they have different thermal conductivities." From our perspective, both the first reply attacking the claim and the second reply attacking the grounds constitute rebuttals of the initial claim that the "objects stay different temperatures."

Because our definition of rebuttals includes attacks on the claim in addition to attacks on the grounds supporting the original claim, however, our version of the coding scheme results in an elevation in the ranking of some of the episodes in comparison to the results of Erduran et al's hierarchy. We acknowledge Erduran et al's rationale for coding social debates but assert that our definition correctly values the epistemic operation of attacking a portion of the claim directly in this type of debate, particularly when accompanied by appropriate grounds. We have discussed this issue with Jonathon Osborne (2004) of Erduran et al. (2004) in person, but further work will be required to refine the value and quality codings for the valid epistemic moves that students make in argumentation. Regardless, because of this difference in coding definitions, we do not intend for the scores to be directly compared in terms of which curriculum resulted in "higher" or "lower" scores. Rather, the scores can only be compared qualitatively simply to suggest that the personally-seeded discussions result in successful levels of argumentation, particularly in light of the scientific context, which Simon, Erduran, and Osborne (2003) found to be more challenging for students than socio-scientific contexts.

CONCLUSIONS

This paper continues the discussion about creating and assessing effective environments to support science inquiry and argumentation. While in-class inquiry discourse typically involves only a small percentage of the students and marginalizes many of the other class members, text-based environments offer the possibility of supporting a much broader range of students (Hsi & Hoadley, 1997). Text-based collaborative environments offer a natural choice because they allow students to participate directly in the linguistic medium of scientific discourse while engaging in inquiry and argumentation. If discourse is important to science, then the opportunity to interact with the actual medium and process of scientific discourse is exceptionally valuable. The results of this study suggest that carefully structured online environments can effectively scaffold student participation in this scientific discourse. The inter-rater reliability results suggest that the proposed coding scheme is also robust in spite of the complex detail with which it analyzes students' participation.

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Why Member Portraits Can Undermine Participation

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Abstract. One possible way to support social awareness in virtual collaborative environments is to provide member portraits. Based on the SIDE-Model (Social Identity Model of Deindividuation Effect) it is argued that these portraits can have ambivalent effects for people who act according to the mode of personal identity and for people who act according to the mode of social identity. An experiment providing an information-exchange dilemma task confirmed these expectations.

Keywords: Group-awareness tools; information-exchange dilemma; participation; member portraits; anonymity; SIDE-Model

FREE-RIDING IN VIRTUAL GROUPS

A problem which is often reported when people exchange knowledge via e-forums or shared databases is low participation. In online seminars, virtual classes or organizational knowledge management projects, many people only passively participate in the information-exchange activity by reading the other participants' messages and contributions, but they do not actively engage in making their own contributions. This high rate of free-riding could have multiple reasons: The topic being dealt with may have low intrinsic value for the participants and thus would not motivate all persons to engage in exchanging their knowledge. But even if group members are motivated to make some contributions, there is a high message threshold. People perhaps are afraid of making incorrect statements which they cannot delete afterwards, or they feel that they have not reflected upon their contributions long enough to write them down. A further obstacle is that it takes additional time and effort to externalize knowledge, because personal knowledge must be written down and worked out in a way that others can understand it. And in many – mainly organizational – contexts unique knowledge serves as power, and contributing it to a database and thus sharing it with others would mean losing this power. All these barriers for contributing raise individual costs for a contributor. And these costs lead to the situation that the decision to externalize knowledge and enter it in a shared repository represents a kind of *social dilemma* (Cabrera & Cabrera, 2002; Cress & Hesse, 2004; Dawes, 1980; Thorn & Connolly, 1987): A potential knowledge provider receives no private benefit for entering information. Instead, s/he only incurs the private costs of investing time and effort. So whereas all the other users can (at least potentially) benefit from his/her knowledge-sharing behavior, the contributor personally has no direct benefit, only costs. This means that every person would benefit more if s/he behaved unco-operatively and withheld their information. But if all individuals did this, there would be no knowledge exchange and everyone would have more costs than if all had co-operated. In the long run everyone would end up less well off.

This social dilemma is even heightened by the anonymity of computer-mediated communication. In newsgroups or virtual classes group members typically are working at different places, they often do not even know each other personally. Exchanging knowledge via shared repositories provides almost no social cues and thus reduces communication to the transfer of information. On the one hand, a sender does not know the recipients and is not informed about the information they need. This could lead to a contributor's subjective perception that s/he sends a message to the database, not to other people. On the other hand, a recipient doesn't have much information about a sender. S/he primarily feels that s/he is retrieving data and not that s/he is obtaining information from a real person. Thus, databases provide an extremely low level of social presence. This makes it even more difficult for each group member to feel him/herself as belonging to a group. A person therefore may feel primarily motivated by his/her own needs, and not affected by the needs of the group, because s/he is not really aware of the others. This low awareness of the group could even increase the tendency of users to supply primarily their own wants, not the wants of others. Thus in a social dilemma, where the individual's benefit opposes the group's benefit, a person will probably be even less co-operative. This carries over into the information-exchange dilemma where a person will contribute less. Taking this effect of anonymity into account, one way to encourage contributing information to a shared database might be to implement database tools which enhance a person's awareness of the others and their needs.

TOOLS FOR PROVIDING GROUP AWARENESS

In virtual environments Carroll, Neale, Isenhour, Bosson, and McCrickard (2003) differentiate among three forms of awareness, which can be strengthened by specific tools. *Social awareness* is a user's awareness of the presence of other group members. It reflects the question "Who is around?". It can be enhanced by any tool which makes the presence of others visible, for example by portraits of others, by video or by avatars. *Action awareness* provides information about "What is happening?". This kind of awareness considers not only the presence of others, but also their interactions with the shared resource. Tools enhancing this kind of awareness make the current action of the group members visible. The third kind of awareness is called *activity awareness*. For this kind of awareness the common task of the group is central. Activity awareness does not only consider who is around and what these people are doing, but it specifically relates the members' actions to the common task. Activity awareness tools provide feedback about whether shared plans are created or changed, and they show how much these shared goals have been reached at any given moment. They provide awareness about "How things are proceeding?".

If shared repositories are primarily used for information exchange in general and not for a joint task, then the virtual environment should support at least the first two forms of awareness: Social and action awareness. In this context many communication platforms allow integrating visual portraits of each group member and feedback about the group's activity. These options are provided with the aim of giving the group members at least some impression about the others and some awareness of the group as a whole. In line with this, current research about social awareness normally assumes that awareness enhances individual participation. This research expects that being aware of the group members and having information about their behavior enhances the feeling of being part of a group. It is expected that this awareness automatically makes the group and its interests come a bit more to the fore, whereas it makes the individual interests less salient

Indeed, experimental studies in our laboratory showed that providing people with information about others' activities does not always have a positive effect (Cress & Hesse, 2004). In the information-exchange dilemma people adjust to the others' behavior. If they receive the information that others are contributing much information then they increase their contribution rate, too. But if they become aware that the others are free-riding, then they reduce their activity, too. So, activity awareness seems to satisfy a human's need for comparing him/herself with others (Festinger, 1954). If people know how others are behaving they tend to assimilate their own behavior to that of the others. For high contributors this leads to making fewer contributions in future.

Based on this ambivalent effect of a tool for action awareness, we have to consider that a tool for social awareness could perhaps also have an ambivalent effect. There is in fact some prominent theoretical evidence in social psychology which indicates that reducing anonymity by providing member portraits could achieve an ambivalent effect, too.

EXPECTED EFFECT OF MEMBER PORTRAITS

Providing member portraits reduces visual anonymity. In the last 10 years much research has been done in the context of the Social Identity model of Deindividuation Effect (SIDE, Lea, Spears, & de Groot, 2001; Postmes, Spears, Lea, & Reicher, 2000; Spears, Lea, & Postmes, 2000). The cognitive part of this research deals with the visual anonymity in computer-mediated communication groups. The concept is based on the theory of Self-Categorization (Turner, Hogg, Oakes, Reicher, & Wetherell, 1987), which postulates that in a group situation an individual has two possibilities to categorize him/herself: One will view him/herself as an individual (personal identity), or as a group member (group identity). These two modes of self-categorization influence the perception and cognitive representation of the group members and the schemas which are activated: In the mode of personal identity a person accentuates the differences among the group members and the group norms become less relevant. Thus individual norms are salient and a person in the mode of personal identity will primarily behave according to his/her own norms. In the mode of group identity, the group is salient and a person primarily views himself as a group member. In this mode the group norm becomes salient and existing differences between different group members are ignored. This leads to a higher conformity to the group norms.

The SIDE model is grounded in this theory and postulates that visual anonymity has different effects for people in the mode of group identity and for people in the mode of personal identity.

- For people in the *group identity mode* anonymity ensures that the only information a person receives is the information that all group members belong to one common group. All individual differences between the group members are masked, which increases the salience of a common identity and leads to stronger depersonalization. This strengthens a person's conformity to the group norm. In contrast, if anonymity is reduced (for example through the provision of member portraits), a user implicitly receives information about differences among the group members. The portraits, for example, show that the group members have different genders or different ages, and the portraits activate different stereotypes. These differences lead a user to cognitively represent the others not only as group members, but also as idiosyncratic individuals with different personalities and motivations. This lowers the subjective perception of being part of one group.

- For people in the mode of *personal identity mode* this effect of portraits is just the opposite: Here visual anonymity strengthens the perceived distance of a person to the group, because without any information about others, people do not have any cues about others at all. If portraits are given, then the others become at least a bit more "real" and relevant. This enhances the prominence of the group, and thus strengthens the significance of the group norm.

This theory can be applied to the information-exchange dilemma discussed above. If groups exchange their knowledge via databases, and if contributing information to the database is associated with any kind of costs for the contributor (time, effort, loss of power), then individual interests differ from group interests. A person individually is better off, if s/he does not provide any information. Then s/he saves individual resources, whereas s/he can nevertheless benefit from the others' contributions. Thus, the personal norm in this situation is to withhold information, and the group norm is to contribute information and participate actively in knowledge exchange. Because in a social dilemma individual interests conflict with group interests, both norms – the individual norm as well as the group norm – are salient. We suppose that then a person's *social value orientation* determines which norm is more influential. The social value orientation is a personal trait, stable across time and situations. According to McClintock (1978) people can be classified into three types of social value orientation: individualistic orientation (persons who mainly behave according to maximize their own benefit), prosocial orientation (people who mainly behave according to maximize the group's benefit), and competitive orientation (people who intend to maximize the distance between their own outcomes and those of the others). About 43% of people belong to the first type, about 28% to the second type and about 8% to the third type. About 20% can't be classified as belonging to one type (Van Lange, Otten, De Bruin, & Joiremann, 1997).

Based on the SIDE-model, we expect that providing member portraits will lead to a higher number of contributions for people with individualistic orientation individualists, but to a lower number of contributions for people with prosocial orientation, revealing an ambivalent effect of member portraits as a group-awareness.

EXPERIMENT

The following experiment, providing a knowledge-exchange dilemma, was conducted to test this hypothesis.

Method

Participants and Design: Participants were 84 students of the University of Tuebingen, Germany (45 women, mean age 23.8 years). They were randomly assigned to the two experimental conditions. Half of the participants were provided with member portraits, half worked without such portraits. Based on the social-orientation test the participants were classified as having a prosocial orientation or an individualistic orientation. This led to a 2 x 2- factorial design.

Material: For measuring the social value orientation we used the nine-item decomposed game measure of Van Lange, Otten, De Bruin, and Joireman (1997). With each item a participant has to decide how many points s/he and another person would receive. The three options represent a prosocial (large joint outcome, and no difference between one's own and the other's outcomes), an individualistic (largest outcome for oneself), or a competitive decision (large difference between one's own and the other's outcomes). Participants are classified as prosocial, individualistic or competitive, if at least six choices are consistent with one of these social value orientations. This test has generally revealed good internal consistency and test-retest reliability. In this study only people with individualistic or prosocial orientation were considered.

Procedure: Upon arrival each participant had to complete the social value orientation test. Then the experiment began: Each participant was told that s/he was a member of a group of six synchronous working team members each working in a different room. This team had to calculate salaries of salesmen and each team member was paid according to the number of salaries s/he managed to calculate. Each salary was composed of two values: a base salary which had to be calculated in the first phase of a trial, and the provision, which had to be calculated in the second phase. In the *first phase* a subject earned 0.25 Euro for each base salary s/he calculated. After each calculation a person had to decide whether s/he wanted to contribute this result to the shared database. But the transfer to the database cost time. And because the first phase was time-limited (9 Minutes), the more one contributed, the fewer base salaries one could calculate, and - consequently - the less one earned.

In the *second phase*, each group member had to calculate the *total salary* of as many salespeople as possible. In this phase a participant earned 0.30 Euro for every total salary s/he calculated. But for the calculation of a salesman's total salary the base salary was needed. If a participant did not calculate it in the first phase, and if this value was not contributed to the database by at least one of the other group members, s/he had to calculate it in the second phase. By doing this one lost time. And the second phase was also time limited (12 Minutes). Thus, during the second phase, the more base salaries the database contained, the more one could earn. Thus, being collaborative and contributing base salaries to the database in the first phase could facilitate the performance of the other group members in the second phase. But according to his/her own payoff, a person had no benefit from contributing a base salary to the database, because in the second phase a person had the base salaries s/he had calculated in the first phase anyway. After the experiment participants were paid according to their individual performance. A person got money for each base salary and total salary s/he calculated. For eliminating group effects the teams were faked. (The task is described in detail in Cress, Barquero, Buder, & Hesse, i.p.).

In the experiment half of the participants worked with a shared database providing member portraits, which were visible during the whole experiment. The other half worked with a screen providing no portraits. At the end of the experiment the participants had to complete the post-experimental questionnaire. Then each participant was paid according to his/her individual performance.

Results

The social value orientation test classified 40 participants as prosocials, 23 participants as individualists, and 9 participants as competitors. The other 12 participants could not be classified as they had no stable tendency across the 9 items of the Social value orientation test. (This proportion of prosocials, individualists, competitors, and non-classifiable persons correspond with the findings of Van Lange et. al., 1997). For testing the hypothesis only people with individualistic orientation and those with prosocial orientation were considered. This lead to the following cell frequencies: 14 participants with individual orientation worked with portraits, nine worked without portraits. Out of the people with prosocial orientation 20 worked with portraits and 19 without.

For testing the expectation a 2x2-factorial ANOVA with the between-factors social value orientation and portraits was calculated. The contribution rate (number of results one contributed distributed through the number of results one calculated) served as dependent variable,. The analysis revealed a significant main effect for social value orientation, $F(1, 58) = 11.42$; $p < .001$: Individualists contributed less than prosocials. As expected, there was no main effect of anonymity, $F(1, 58) = 0.25$; $p > .05$, but there was a significant interaction between social value orientation and anonymity, $F(1, 58) = 4.28$; $p < .05$. The mean contribution rates of the four conditions describing this interaction are presented in Figure 1. It shows that for people with individualistic orientation the portraits lead to higher contribution rates, whereas for people with prosocial orientation they lead to lower contribution rates.

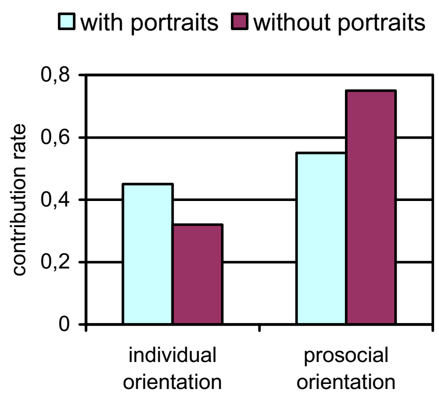

Figure 1: Mean contribution rates for participants with different social value orientation working with a shared database providing portraits of the others, or with a shared database not providing any information about others.

Discussion

The study confirmed the hypothesis resulting from the SIDE-Model: In the information-exchange dilemma member portraits have different effects for people with individualistic and for people with prosocial orientation. For individualists portraits enhance contribution, whereas for prosocials they undermine contribution. This result strengthens our argument that group awareness tools in virtual environments do not necessarily have the desired effect of enhancing participation. Social awareness tools can make the group more prominent by reminding a group member of the existence of other group members. But they also can provide the information that the other group members have different needs and that they behave differently. This information, which can be implicitly transported by a group awareness tool, could reduce one's perception of the group as a monolithic block. And perceiving individual differences can reduce the motivation to act in favor of the group.

In this context, the study of Lee (2004) is interesting. His experiment is also based on the SIDE-model, and it investigates different forms of member visualizations in computer-mediated communication. The participants of a group were either visualized through same-character cartoons or through different-character cartoons. Lee found that the same-character cartoons made the group more salient than the different-character cartoons. The groups with the same-character cartoon depersonalized themselves more and showed more conformity to the group norm during the discussion. So, even if both forms cartoons provided full anonymity, the same-character cartoons made the group more salient than the different-character cartoons. Lee and Nass (2002) further showed that even if people are fully aware that the characters are randomly assigned to the discussion partners, they associate the attributes of the characters with anonymous communication partners.

The results of our study raise the question as to whether there are alternative visualizations which could avoid the undesired effects of the group awareness tools developed so far. Such visualizations should enhance social awareness by making the existence of others more prominent. And simultaneously they should stress the perception of homogeneity of the group members. In further experiments we therefore will investigate the use of a pie chart which is programmed in a way that the pie piece of a member locks into place as soon as s/he is online. If all group members are present the pie is complete and is visualized as a united entity. We assume that such a chart could make the group salient by reminding a person about the existence of other group members. It gives information about the number of people belonging to the group, and it presents their names. But these persons are all visualized in the same manner, and the pie chart stresses their togetherness. It makes the group as a whole salient and leads a person to a stronger feeling of being member of a group.

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ICT Can Recover Collaborative Tutorial Conversation and Position It within Undergraduate Curricula

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Abstract. A procedure is described for mobilizing ICT resources in order to implement collaborative tutorial conversations with large undergraduate classes. The method allows intense, intimate and regular face-to-face conversations the consequences of which are used as grounding for traditional lecture presentations. Data from focus group discussion, system logs, and measures of student contribution indicate the intervention ran smoothly, was popular, economical and effective.

Keywords: University, tutorial conversation, interact ional practices

INTRODUCTION

What forms of collaborative learning should be most vigorously cultivated? And how should such collaborative encounters be effectively integrated with the wider experience of an undergraduate subject curriculum?

Arguably, the most precious from of collaborative learning is that arising in the (scaffolded) conversation of a traditional tutorial group. After all, it is within just such intimate exchanges that so much informal learning takes place in our preschool years (Wood, 1988). And it is just such conversations that we most anxiously protect during, for instance, postgraduate supervision - and within other apprenticeship settings (Lave and Wenger, 1991). Yet in higher education these encounters have now been rendered almost obsolete by increasingly unfavourable staff-student ratios.

Computers have long been regarded (quite rightly) as a positive resource for promoting collaborative learning (Crook, 1994, O'Malley, 1994). Yet, if anything, this technology has tended to undermine rather than support the form of collaborative tutorial conversation identified here. Computers facilitate *other* sorts of collaboration – and do so very usefully. But, most commonly in conventional higher education, these collaborations are either asynchronous and text-mediated, or they are project-oriented peer interactions where the computer provides learners with a shared problem space.

Yet asynchronous exchange may fail to capture the momentum of live tutorial conversation – and it has never been attractive to full time students (Lightg, Nesbitt, Light and White, 2000). And computer-mediated peer interactions may not be practical to implement in many disciplinary contexts. (Moreover, such interactions may lack the conversational direction and momentum that a tutorial format can usefully bring.) It is proposed here that, however much we may wish these mainstream forms of CSCL to flourish, they should not be perceived as inevitable substitutes for tutorial collaborative talk. So, this situation presents an empirical challenge: can ICT provide a way of protecting and promoting such talk and, if so, how? An ICT-mediated procedure for doing so will be described in this paper.

A subsidiary concern here is with the effective *integration* of conversational learning encounters: getting them linked to the wider undergraduate curriculum. Too often, occasions of collaborative learning are decoupled from a larger learning narrative in which they should be situated. This can certainly be the case for research-led interventions: where innovative mediated encounters (although novel and engaging) are often simply parachuted into an ongoing curriculum. In the present context, this concern for integration suggests asking both: "where should the motivation for collaborative tutorial talk come from?" and, then, "where should it lead to next?" In other words, how do these encounters become "joined up" into the surrounding curriculum of other learning events?

The present report describes outcomes from an intervention that mobilizes ICT to economically achieve collaborative tutorial conversation within a large class – while integrating that talk into the surrounding curriculum of the course. The goal was to define a suitable ICT infrastructure to mediate these encounters. The theoretical rationale for curriculum integration was taken from Schwartz and Bransford's (1998) account of grounding lectures in prior activities of topic "differentiation". In this account of good educational practice, Schwartz and Bransford identify "differentiation" with periods of (usually hands-on) experimentation with domain materials that serve to sharpen learner awareness of crucial discinplinary distinctions and processes. This differentiation then becomes a firm platform for engaging with the "telling" that will go on within lectures and other sessions of teacher exposition.

CONTEXT

The starting circumstances for implementing tutorial collaborations were familiar (and daunting): a class of more than 80 traditionally full-time Psychology undergraduates allocated a weekly timetable slot (for instruction in "Social Development"). Five hours private study per week was also assumed. In sympathy with Schwartz and Bransford (1998), it was felt important to protect one of these two hours in order to organize the "time for telling" that was to be built on the experience of topic differentiations. This meant that any tutorial conversation would need to be orchestrated by the two instructors and two postgraduate assistants such that small (N=3/4) self-selected groups could meet fortnightly for discussion. This could only work if two conditions obtained. (1) The traditional one-hour discussion format was replaced by an intense *20-minute* format. (2) Tutors and students could be orchestrated to be suitably prepared for discussion and suitably informed as to when and where they should be for such a tightly framed encounter. Shared ICT resources made this possible in relation to three organizational issues.

These "prompts" for the conversations might be photographs, artifacts or formalisms such as diagrams or data summaries. Examples are shown in Figure 1 (although each may have been one among several).

Figure 1: Image, artifact and formalism examples of web-based tutorial prompts

The first is a photograph, and it is aimed to help differentiate the topic of infant attachment. The second is a child's drawing and is intended to help differentiate the topic of graphic representational development. The third is a formalized description of playground affiliation and is intended to prompt a discussion of friendship and status in early school years peer groups. Once again, a shared ICT infrastructure of web pages makes the preparation and presentation of these prompts straightforward. While the email system eases the process of alerting students to the location of the material they are to make the basis of reflection.

METHOD

The class was organized into 24 self-allocated tutorial groupings. Each would meet once every two weeks, the conversation being led by one of the four tutors, on a rotating basis. Institutionally shared ICT resources were recruited to coordinate these encounters in the following manner.

1. <u>Attendance</u>: students rotated around tutors on a fortnightly basis. An excel-based process was created to email individual reminders two days in advance. The process calculated each student's destination that week, specified it, and incorporated a direct link to a web page that contained the preparatory material.

2. Preparation: the web page provided grounding for discussion. It typically contained images that requested informal psychological interpretation. Each student was primed to speak for up to 2 minutes each on how they understood the images presented. A tutorial discussion then developed this.
3. Reflection: one group member acted as scribe and, by the following day, entered notes in a course web page text box. These were collated such that combined notes from all 12 groups meeting in a week were made visible for the whole class.

FINDINGS

The initiative was evaluated in terms of sustaining attendance, quality of scribe summaries, use of these summaries, and focus group commentary by student and tutor participants. Although attendance was not policed, it averaged 92% across the semester with most absences being accounted for by illness. Scribe reports were reliably presented within two days and, as shown in Figure 2, were typically substantial for a 20-minute confersation: around 400 words in length (a little shorter than the Introduction to this report), a commitment that remained steady across the 14 weeks.

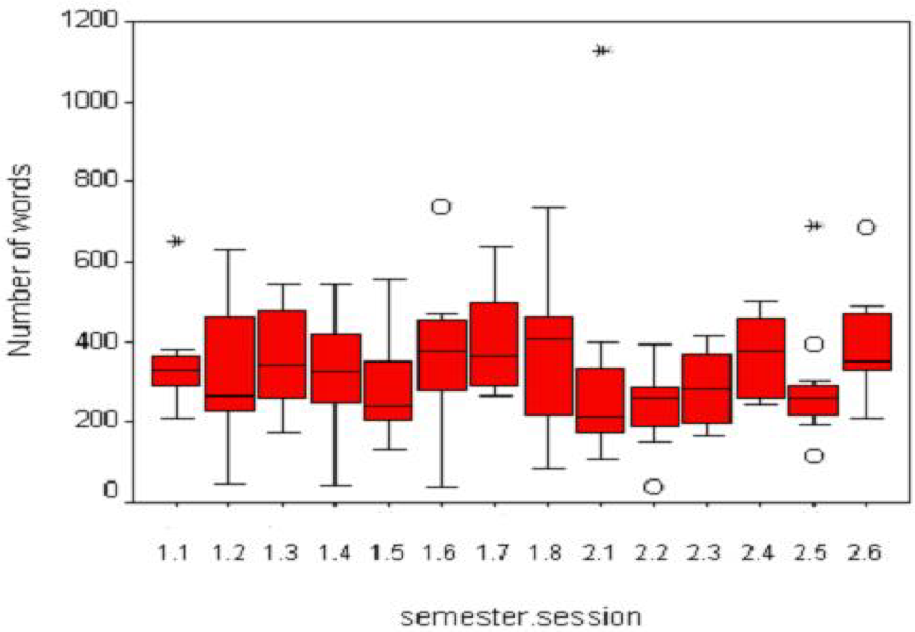

Figure 2: Length of scribe reports across the 14 weeks taken from two semesters

The collated sets of summaries were available on a single web page. These received a moderate level of consultation by other students (the average posting attracting attention from around 30% of the class). Focus group discussion suggested many students felt their own conversation had covered what the wanted to know, or they would rely on the start-of-lecture summary to bring them up to date. Yet other students reported finding it refreshing (and sometimes surprising) to see what other groups had decided and discussed. In some cases the discussions had taken very different directions and convergences. No pressure was put on students to make use of these resources yet the way in which those that did reacted to them suggest that this is a potent source of supplementary material that is worth knitting into the mainstream of a course curriculum.

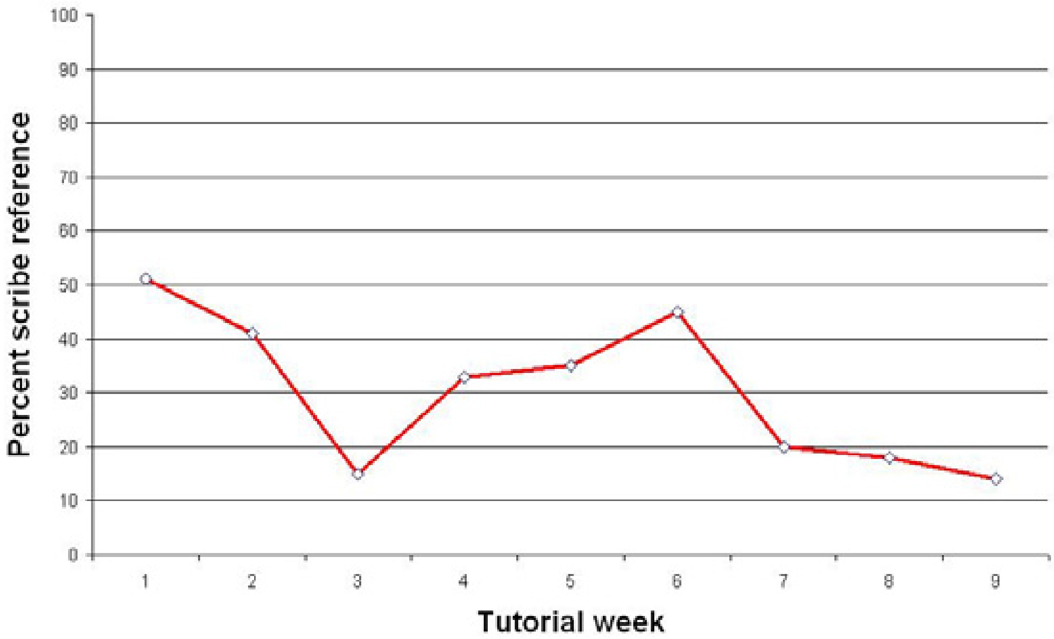

Figure 2: Average percent of class referring to a web page containing collated scribe reports.

In a group discussion, tutors confirmed that discussions had been universally on-task, well prepared, thoughtful and animated. In three focus group discussions, comprising volunteer members of randomly invited groups, a number of recurring themes surfaced. Students felt that the opportunity for academic conversation with staff – albeit short and occasional – created a stronger sense of being "recognized" within the normal anonymity of large class degree programs. It was also felt that the conversations located the more abstract content of the lectures in a grounding of common sense familiarity – as furnished by the everyday nature of some of the web images that served as discussion prompts. Conversations were experienced as harmonious and "collaborative" or "problem solving" in tone.

DISCUSSION

The study has illustrated a realistic and economical structure for recovering the tradition of small group tutorial conversation. These have been characterized here as "collaborative", as this is the spirit in which they were introduced to the students and managed by the tutors. Moreover, the style of conversation that actually evolved was described by the participants during the focus groups as equable and exploratory. However, it must be stressed that these collaborations were crucially "computer-supported" collaborations, in that they could not have occurred without the infrastructure of email servers, database management tools, and shared institutional web pages (including facilities for uploading text). It is also important to stress that none of these facilities are technically sophisticated. The general procedure described here is within the reach of the ICT infrastructure enjoyed by most higher education institutions.

Although others have explored the use of ICT for small group discussion (e.g., Anderson et al, 2000), the present intervention extends previous initiatives by establishing a system for resourcing, assembling, and documenting these meetings that is sufficiently automated to support large classes economically. Yet the actual meeting successfully protects the familiar genre of conversation associated with small group tutorials. Traditionally, such tutorials would last around an hour. The short and intense meetings developed here became known as "speed tutorials". Both tutor and student participants found them, if anything, more productive than the traditional format. They kicked off more sharply, discussion remained on task, and there was strong sense of needing to converge on a set of questions or uncertainties.

Of course, these were integrated with the following lecture session: the two stage process was an attractive structure to realise Schwartz and Bransford's (1998) agenda of topic differentiation proceding expository "telling". The public web posting of the summaries gave the lecturer time to shape his lecture such as to accommodate and make explicit reference to the issue raised in the tutorials. This created a strong sense of informal and intimate collaborative discussion being integrated into the evolving body of a traditional course.

Arguably, it is unusual for the products of collaborative learning encounters to be knitted into the overall fabric of a course in this manner. The technique reinforces Schwartz and Bransford’s proposal that lectures (“times for telling”) are most effective when they are resourced by prior experience in which students have actively differentiated the subject matter that is to be systematized or theorized in the lectures. Schwartz and Bransford achieve their student preparation through exploratory practical work. For the present topic, student practical work involving young children would be ambitious to organise. Thus our version of topic differentiation was achieved in collaborative conversation, although grounded in everyday images.

In sum, this report has presented a credible basis for prompting, supporting and integrating a form of collaborative conversation that is increasingly becoming lost under pressure of large class teaching. It might be argued that the “tutorial” dimension of these meetings is a luxury. That groups might be convened on a self-managing basis and the system remain just as successful. Our previous experience of such initiatives have not been encouraging. Moreover, in focus group discussion, students reinforced the value of having a tutor presence within these groups. We suspect it is a significant presence for both sustaining the direction and target of the talk – as well as for reinforcing and developing its insights.

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Researching "Collaborative Knowledge Building" in Formal Distance Learning Environments

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Abstract. Distance learning environments provide a rich opportunity for collaborative knowledge building, particularly through peer-to-peer dialogue. Much of the discussion in distance learning environments occurs in asynchronous forums, and it is content analysis of these discussions that constitutes the majority of research in online learning. However few studies in this area provide enough information about the context to know what works and what doesn't. Most studies do not go beyond downloading and analyzing the transcripts after the course is completed. Studies also lack a solid epistemological stance, attempting to capture evidence of individual learning of knowledge rather than examining the process of group learning through knowledge construction. An ongoing lack of attention to a coherent theoretical foundation, examining transcripts without attending to their situated contexts, and relying primarily on reductionist content analysis methods, will continue to limit our understanding of the potentiality and actuality of online collaborative learning environments. In this paper we explore how Stahl's social theory of CSCL can be applied to formal online learning environments to address these limitations.

Keywords: Online discourse, collaborative knowledge building, discourse analysis methods

INTRODUCTION

Internet-based distance education is one avenue for computer-supported collaborative learning. However, distance education contexts vary as widely as any CSCL context in terms of learner populations, technology, learning goals and learning tasks. Research in distance learning environments have tended to be exploratory case studies in which discussion transcripts are downloaded and analyzed after the course is completed, either by the instructor of the course or an outside researcher. The full context of the case study is often not described as recommended by case study methodology (Stake, 1995; Yin, 1984). Analysis has relied mainly on frequency counts of participant posts and/or coding and counting phenomena through content analysis (Hara, Bonk & Angeli, 2000; Henri, 1992). The primary purpose of these studies seem to be to account for individual learning through the discussion process, but as pointed out by Rourke and Anderson (2004), there is often no clear epistemological stance taken as to what constitutes learning and how we might examine it.

In this paper we explore limitations of the current research on distance learning environments, particularly research which relies on analysis of discussion transcripts. We suggest that Stahl's social theory of CSCL may be used as a theoretical framework for understanding these environments and ultimately designing them more effectively.

EPISTEMOLOGICAL STANCE

Traditional notions of learning and assessment tend to favor product-based outcomes over process-based ones, particularly focusing on individual learning. However, assessing process can be just as important as assessing product, especially if educators want to know which learning activities and methods are contributing to collaborative knowledge building. In the case of online discussion, it becomes necessary to first determine the purpose for being engaged in the activity. What is actually occurring as students talk together? Are the students learning from the conversational interactions, or are they simply participating because it is what they are supposed to do (e.g., because someone is counting how many posts they make)? And if their discussion participation is being assessed, does that assessment focus on quantity of messages, quality of messages, or evidence of learning through, for example, a process of constructing new knowledge?

Determining whether or not learning took place as a result of engaging in discussion is not simple. Students often intuitively orient towards discussion as a "show what you know" activity rather than an "explore this topic" activity. In other words, they tend to naturally position themselves toward an objective knowledge that they will try to learn or adopt, assuming the instructor will assess them based on how much of it they have come know. Course assessment methods, as noted above, often favor such beliefs. However, if the purpose is for individual students to communicate what they know to an instructor, why do so in a public forum such as a discussion board? Clearly there are other underlying epistemological beliefs or needs that drive our desire to engage groups of people in discussion on a particular topic.

There has been some movement away from this transmission view of learning to the notion of learning as mediated communication between people. Hill, Wiley, Nelson and Han (2004) characterize this difference as learning "from" and "with" the Internet to learning "through" the Internet. Online discussions are particularly rich environments for true knowledge creation to take place, but only when designed in ways that engage students in dialogue. Thus far most studies do not clearly delineate what is meant by learning. Rather than viewing participation alone to be evidence of learning, we define learning as a process, demonstrated through conversation, in which learners reflect upon what they currently know and negotiate new meaning and knowledge creation with others through conversation. Together groups come to new understandings through conversation. Closely examining these processes is how we assess learning.

PROMINENT METHODS AND LIMITATIONS

At the present time, there is lack of clear guidance for which data collection and analysis methods might best capture and explain the learning that takes place in online discussions. Campos (2004) points out that "research goals, theoretical perspectives, and methods vary across studies and are not replicated. The result is a very heterogeneous corpus of scientific research that could be defined as exploratory" (p. 4). Rourke and Anderson (2004) also report that most studies remain in the preliminary tryout stage and add that many of these studies lack normative data to be able to generalize the results.

A useful start, then, may be to categorize and review some of these studies in terms of what research questions they address, contexts they examine, and epistemological stance taken. Marra, Moore and Klimczak (2004), Paavola, Lipponen and Hakkarainen (2002) and Meyer (2004) have initiated work in this area. Marra et al. (2004) compared two commonly used coding schemes (Newman, Webb & Cochran, 1996; Gunawardena, Lowe & Anderson, 1997) for their relative advantages and disadvantages. They concluded that it was difficult to apply these content analysis schemes without looking at the *context* of the discussion task and the discourse as a whole, arguing that it is necessary to move beyond looking at only the transcript itself. Meyer (2004) applied four coding schemes (King & Kitchener, 1994; Perry, 1999; Garrison, Anderson & Archer, 2001; Bloom & Krathwohl, 1956) to the same set of data and noted that the type of triggering *question* posed by students in online discussions greatly impacted the outcomes. Meyer suggested that "it might be worthwhile to analyze the ebb and flow of online discussions as a *group* [emphasis added] effort, rather than focusing on the *individual* postings as a reflection of the student's level of thought" (p. 112). Finally, Paavola et al (2002) moved beyond critiquing content analysis schemes to comparing three knowledge-creating models, emphasizing that all three models posit knowledge as "part of a dynamic process of innovation embedded in various skills, emotions, and hunches of the people involved . . . [and]bring in conceptual artifacts, theories, activities, questions, problems, metaphors, dialectics as mediating factors" (p. 12).

Participation, content, and structure of online conversations all are areas that are being explored by researchers. Each focus yields some useful descriptive results about the interactions that take place, but each also has significant limitations in terms of what we find about how discussion impacts learning processes.

Participation

The very earliest studies of online discussion typically focused on measuring participation as a primary indicator of interaction, which was sometimes the sole determinant of "learning." Indeed, this type of focus often mirrored the instructor's assessment of the discussion activity. One cannot dispute that participation is necessary in order to have interaction as well as to enable learning via discussion boards, but it is not a given that participation and interaction will result in learning. Quantity of participation is not the same as quality, and even quality may be broadly defined, since a good question may be just as important as the answer. For example, Pear and Crone-Todd (2001) claim to look at social constructivist learning in a computer-mediated setting by measuring the number of minimal and substantive feedback messages students received from other students. Unfortunately, this study does not address the effects that such feedback had on the learners, nor does it look at the quality of the feedback. It is possible that a brief or minimal feedback message could be sufficient in some cases, particularly if all that is needed is affirmation, and that a substantive one might be too authoritative or could lead the learner off-track.

Participation may well be an indicator of social presence (Rourke, Anderson, Garrison, & Archer, 2001a), a construct that may be important to creating a sense of community among online learners. While we do not minimize the importance of social presence, it does not in and of itself lead to collaborative knowledge building through dialogue. Vicarious learning through lurking is another phenomenon that has not been fully explored and is not accounted for through participation counts (Beaudoin, 2002).

Content

A shift from quantity of discussion to quality of discussion emerged most notably with Henri's (1992) oft-cited coding scheme. Most coding schemes created to investigate quality of online discussions draw upon content analysis methods (Bauer, 2000), translating discourse into either nominal data (e.g., gender, or type of message) or ordinal data (e.g., scale or rubric-based quality ratings). These frameworks provide researchers ways of dealing with potentially large quantities of qualitative data and achieving generalizability, but often suffer from a tension between the rich qualitative data and the resulting interpretive – and often reductionist – quantitative methods.

Concerns about the threats to reliability and validity inherent in these content analysis frameworks have recently been raised (Rourke & Anderson, 2004; Rourke, Anderson, Garrison & Archer, 2001b; Campos, 2004). Studies that are cited quite often in the literature on online discussions (e.g. Henri, 1992; Newman, Webb & Cochran, 1997; Howell-Richardson & Mellar, 1996; Gunawardena et al, 1997; Kanuka & Anderson, 1998) are criticized for including too few details about coding procedures, being inconsistent in the units of analysis, and not detailing a solid epistemological stance.

All too often the transcripts are simply downloaded and the conversation unitized, coded and counted. At the same time, these studies are positioned as case studies, but in actuality provide few details about the context of the study – what tasks were being completed, the role of the facilitator, etc. This reductionist view eliminates the context. Fuller data collection methods are needed to understand the CSCL environment and how learning takes place – not learning as received knowledge, but learning as knowledge creation through interacting with a group that it is then internalized and interpreted by individuals.

Structure

Discussion boards readily generate both quantitative and qualitative data. In terms of quantitative data, one can count the number and length of messages, the depth of threading, the span of time between messages and responses, and the number of hits on a particular message. Each of these data types may be reviewed for the individual contributor as well as in aggregate for a thread or a group of discussants. They can provide indicators of the general structure of interactions that are taking place in a class, but are really lacking in terms of indicating quality or nature of interactions. For example, a one-sentence message could be a thought-provoking question or an idle statement of agreement with a previous post, and a long message might present a lot of useful thoughts and encourage others to contribute or it might become overly pedantic and shut down further discourse.

Social network analysis is a useful method for demonstrating the relationships in a given social network (Scott, 2000). This method can be used in the context of online discussion to demonstrate if discourse is centered around people in positions of power, such as the instructor, or individuals with other notable characteristics. For example, Aviv, Erlich, Ravid and Geva (2003) used network analysis to examine how power roles affected engagement in critical thinking activities in differently structured online courses.

They were able to use the method to elucidate cliques that formed within the studied classes and determine who took leadership roles. However, this method still does not shed light on whether or not students are learning via their engagement in the discourse and favors visible engagement (i.e., message posting). It can reflect students who are more dominant or extroverted when it come to argumentation, but does not indicate whether or not their ideas were well-founded, or if others were learning from them.

Similar to social network analysis is sequential analysis (Bakeman & Gottman, 1997), which looks not at how individuals or other social entities interact, but rather at how particular actions or events are sequenced, with characters or roles being only of secondary concern. Jeong's (2003) Data Analysis Tool uses sequential analysis to quantitatively describe student interaction patterns in an argumentation-oriented learning context. Two-message sequences were considered the unit of analysis (e.g., initial message and response) in Jeong's study, which examined the relationship between sequences and potential indicators of critical thinking skills. While this method is quite useful to develop descriptive models and demonstrate probabilities of particular interaction types, such as a statement of agreement following one of disagreement, it does not indicate whether or not learning is taking place through these interactions. Further, it reduces each message to a particular code which might be considered oversimplification in some contexts. For example, in Jeong's study a message of conditional or partial agreement would be coded as neither agreement nor disagreement, but rather "negotiation." Such messages, however, might represent the true spirit of negotiating meaning amongst participants or might simply represent a student with a strong set opinion that does not neatly fit either side of an argument.

APPLYING THE METHODS

In this section we illustrate how the various analysis methods can each lend some insight, but not a comprehensive picture of how groups learn in a social context. Here is a transcript from an asynchronous discussion forum:

> ***Toilets ,Eddie***
>
> We, as a society, definitely take running water for granted. A few days ago I had no water because of work on a line. My water was off for about six hours. Horrible. I couldn't make ice tea, take a shower or anything. Eventually the water did return and all is well. Just think of the poor countries were the running water never even appears!
>
> ***Re:Toilets, Tanya H.***
>
> When I was younger, we visited the South and in order to take baths we would go outside and get buckets of water from the well heat the water up and poured it into a white wash tub. Talk about inconvenient. But since I was a little girl I thought that it was fun. As an adult, if I had to do that, I would be annoyed.
>
> ***Re: Toilets, Laney***
>
> Boy I can relate, we had a back up in our basement due to roots from a tree, and my husband and I wanted to stay at my moms because of no water, how spoiled are we? Does anybody remember when Brownsville had to boil their water due to a bacteria? We all were out purchasing water.
>
> ***Re: Toilets, Clarissa***
>
> yeah...i do remember when the people of Brownsville had to boil their water. my grandmother lives there, and we had to bring her jugs of water to keep her in comfort.
>
> ***Re: Toilets, Donna***
>
> I have to agree with you all. I know that I do take the modern conveniences for granted.

An examination of this brief thread yields different results based on the analytic framework used as follows:

Participation: Analyzing traditional notions of participation or social presence can show us who is talking, but not who is lurking. We see that there are five participants posting. Each person posted once. We can see a friendly tone, informal language, and use of the first person, all of which signal information about the *social* nature of the environment. We do not know who may be lurking or what the role of the instructor is, the task, or the context of the course.

Content: This appears to be an off-topic thread, unless the purpose of the discussion has to do with lack of modern conveniences. It would likely be coded as “surface” learning (as opposed to deep), off-task, or purely socializing because there are no explicit references to the course text or concepts. There does not seem to be a lot of content here related to the formal learning of the course material. We do not know what the purpose of the discussion is or what information came before and after this thread.

Structure: The thread would need to be compared to others to have any analytic utility using this method. Of particular note is that the lone male participant is the thread starter (implying gender-interaction patterns), one respondent asks a question that receives its own response, and that all participants are in agreement. Also each new post explicitly connects to a previous post, revealing that there is intention to build on previous posts.

Thus we see that measures of participation, content and structure can all provide useful information about online discussions. However, they don’t explicitly address indicators of learning, instead they focus on individual descriptive elements of the messages that were posted and, in the case of structural analysis, how the message interrelate based on some variable (gender, timing, etc.) These methods do not yet take full advantage of the context to shed light on how groups create new knowledge together. In the next section we show how Stahl’s social theory of CSCL may help in this area.

NEW PARADIGMS

Stahl's (2002, 2003a, 2003b) social theory of computer-supported collaborative learning focuses on the group as the unit of analysis. Moving from viewing learning as a knowledge-*transmission* process to a knowledge-*creation* process which occurs in conversation with others, Stahl outlines how all individual knowing is in essence an interpretation of a meaning that was first made in conversation with others. But it is only through capturing all verbal and nonverbal communication that we can fully understand the context in which individual utterances function in the context of a group discussion. It is through analyzing the dialogue in context that we can understand how knowledge is created collaboratively:

> The fact that collaborative learning *necessarily* makes learning visible provides the methodological basis for empirical analysis by researchers. Researchers of collaborative learning are not restricted to indirect evidence of learning (such as pre-test and post-test differences) because they can analyze and interpret the making of meaning as it unfolds in the data at the group level and in individual trajectories of utterances . . . Of course, the analysis must also take into account the activity structure and other socio-historical content in which learning takes place (Stahl, 2003b, p. 35).

Thus, it is by looking at the discussion in its broader context, through microethnographies, conversation and discourse analysis methods, that we can begin to understand how a group of discussants creates new knowledge while in conversation. Examining the full context and the dialogic artifacts for moments of new knowledge creation *can in itself be* the evidence of an effective group learning environment. To do this we need: 1) closer attention to the context of the environments; and 2) conversation and discourse analysis of knowledge building within the context.

Micro-ethnographies

Providing a more comprehensive picture of the context of the discourse is also key to generating lines of research that will result in useful prescriptive knowledge, such as instructional design theory. With educational experiences increasingly being offered via interacting online forums by novice online instructors and students, the more detail that can be provided about the context in which a particular strategy worked or interaction took place the better. Using additional data collection methods beyond just collecting archives of a class discussion can help provide this contextual information. In particular, surveys, interviews, and field notes should be considered as possible data collection methods to generate contextual information and help triangulate discussion-based findings. Student surveys can be used to see how attitudes affect one's participation and perception of whether or not learning resulted from a particular activity. For example, Dennen (2004) found that student perceptions of how a discussion contributes to learning often differ from what the researcher sees in the data, with students in a less successful treatment feeling more confident that they had learned than their classmates in a more successful group. Collecting data directly from students also can help shed light on other factors, such as unclear directions, technology problems, or competing assignments, that might have affected participation. Interviews with instructors might yield information about behind the scenes instructions students were given or volume of off-board communications, such as private email, that surrounded the activity.

Field notes may seem like an unusual choice of data collection method for studying asynchronous discussion since discussion boards are self-archiving and do not involve real-time activity. Whereas in face to face environments it is possible to videotape the collaborative interactions to capture not only the dialogue, but gestures and other nonverbal communication important to meaning-making, this isn't possible online. However, there is a 'feel' to the online experience that cannot be captured only by reading transcripts after the fact. Thus, tracking a discussion in progress and keeping notes about it can be particularly useful. An observant researcher may choose to take notes from the perspective of a student, instructor, or outside observer. The prolonged and continuous engagement that results from the researcher watching the discussion as it occurs permits the researcher to comment on what the actual participants might have experienced at different times during the course. Our research presently tends to document completed discussions, looking at the act of message posting. However, students engaged in an online course are likely to be affected by what it means to be a reader of messages, looking for places to post a response or waiting to see if a particular message received a reply. Analysis of archived discourse fails to adequately capture times when the discussion board feels "slow" or inactive; has such rapid participation that it almost seems synchronous; is rich or lacking in openings for true dialogue; or is tense based on a message that may be interpreted in multiple ways. For example, a particular message may seem surprising or radical when initially posted, but become less so as classmates enter and adopt that point of view. Capturing these moments during the actual creation of the dialogue may provide insight into the participants' experience, whereas archives of completed discussions may smooth over or obscure any rough spots that happened during the discussion period.

Conversation and discourse analysis

Rourke and Anderson (2004) and Rourke, Anderson, Garrison and Archer (2001b) describe the enormous difficulty of inferring the presence of an underlying construct, such as knowledge construction, from what is observable in computer conferencing transcripts. "Drawing conclusions about underlying constructs based on frequency counts of the surface content of communication is a complicated analytical process, though it is rarely recognized as such" (Rourke & Anderson, 2004, p. 15). They point out that an iterative process between grounded theory and literature review is often used to come up with behaviors that represent the construct of interest, such as cognition. Campos (2004) adds: "Curiously enough, most of those studies considered qualitative rely on quantitative measurement of qualitative categories. [This can] indeed suggest certain trends. However, such studies are very limited because summing up categories says nothing about the knowledge building *process.* It is only through attention to the process that collaborative conceptual change and learning can be assessed" (p. 4).

When analyzing discussion transcripts, Dillenbourg, Baker, Blaye and O'Malley (1996) admit that "deciding on the meaning of . . . expressions in a given dialogue context is thus quite complex, but necessary if we are to understand when students are really collaborating and co-constructing problem solutions" (p. 18). They point out that a promising possibility is to "exploit selective branches of linguistics research on models of conversation, discourse or dialogue to provide a more principled theoretical framework for analysis" (p. 19). Mazur (2004) and Herring (2004) have begun to explore how linguistic methods of conversation and discourse analysis can be applied to online discussions. Herring's (2004) computer-mediated discourse analysis (CMDA) is "any analysis of online behavior that is grounded in empirical, textual observations . . . [I]t views online behavior through the lens of language, and its interpretations are grounded in observations about language and language use" (Herring, 2004, p. 339). CMDA draws upon theoretical assumptions of linguistic discourse analysis, including the notion that recurring patterns are present in discourse which may be identified by the analyst, even though speakers themselves may not be aware of these patterns. The notion that we *do* things with words can be traced back to Austin (1962) and Searle (1969) and speech act theory. This view of language is particularly useful when seeking to examine how groups complete a *process*. Traditionally, content analysis has revealed *what* participants say online; however, *what participants are trying to do* with what they say online is of particular interest when describing a process such as knowledge construction.

APPLYING THE NEW METHODS AND PARADIGMS

We return now to the sample data thread analyzed above, showing how a deeper understanding of the context and a conversation/discourse perspective is valuable.

Microethnography. Additional information such as the timing of the posts, how this thread fits into the larger discussion forum, the larger context of this particular thread, how many people were lurking, that the students may be communicating face to face or through email in addition to the discussion forum, what was the role of the instructor, what task / prompt were they responding too, and how all of this fits together to capture the knowledge they were creating together. There are often "a-ha!" moments that change the flow of the conversation. These are often not captured, or when used in other methods tend to not be part of contextualization (e.g., looking at timing as a structural element).

In the actual class from which the data sample was taken, these messages were posted in a thread over the course of two weeks. The students were reading about related topics, such as the role that sewages and plumbing technologies have played in developing society. The relaying of personal experiences is actually following a model that the instructor set, encouraging all students to find examples of the concepts being learned in their own lives and to examine what happened when their experiences and knowledge was pooled. Within this course, almost every student was an active participant at some point in time, but they tended to wait and post when they felt they had something to say rather then posting for participation points or to demonstrate that they had done the reading. This particular thread was briefer than many of the others

Conversation analysis: There are four female participants and one male participant. Eddie started the thread and everyone else responded. Each person took one turn. The length of the messages gets shorter as the thread progresses. Everyone generally agrees with each other. Most of the messages consist of statements. There are several questions and some direct and indirect responses.

Discourse analysis:

> ***Toilets, Eddie***
> We, as a society, definitely take running water for granted. A few days ago I had no water because of work on a line. My water was off for about six hours. Horrible. I couldn't make ice tea, take a shower or anything. Eventually the water did return and all is well. Just think of the poor countries were the running water never even appears!

Eddie begins by making a claim that "modern conveniences are taken for granted". He supports this with a personal story and example from his own life, followed by an appeal to bring others into the conversation through his exclamation, "just think….!"

> ***Re: Toilets Tanya H.***
>
> When I was younger, we visited the South and in order to take baths we would go outside and get buckets of water from the well heat the water up and poured it into a white wash tub. Talk about inconvenient. But since I was a little girl I thought that it was fun. As an adult, if I had to do that, I would be annoyed.

Tanya connects by relating her own personal experience/example along the same lines. This is done indirectly and without direct reference to Eddie's post. She however explicitly connects the idea of "as an adult . . . I would be annoyed" to Eddie's initial claim that we as a society take conveniences for granted.

> ***Re: Toilets, Laney***
>
> Boy I can relate, we had a back up in our basement due to roots from a tree, and my husband and I wanted to stay at my moms because of no water, how spoiled are we? Does anybody remember when Brownsville had to boil their water due to a bacteria? We all were out purchasing water.

Here Laney makes a direct connection (reference to the previous post) "boy I can relate" and also brings in her own examples. She also restates the idea of taking things for granted by saying "how spoiled are we?" She searches for an experience that all participants have in common by referring to a local incident in Brownsville. She asks it as a question to draw others in.

> ***Re: Toilets, Clarissa***
>
> yeah...i do remember when the people of Brownsville had to boil their water. my grandmother lives there, and we had to bring her jugs of water to keep her in comfort.

Clarissa directly responds to Laney's question, followed by a personal experience. At this point the posts become shorter, and there is less exploration and more direct respond.

> ***Re: Toilets, Donna***
>
> I have to agree with you all. I know that I do take the modern conveniences for granted.

Finally, Donna weighs in with a general agreement, plus an interesting connection back to the broader concept of "modern convenience" that Eddie had initiated in the first post. The message serves to provide resolution to the thread, somewhat unusual in asynchronous discussion forums (Hewitt, 2003).

Through this discussion the group is exploring the meaning of modern conveniences and taking them for granted and sharing personal stories to illustrate what they each mean and bring it back together again.

Traditional methods of participation, content analysis and structural analysis reveal important insights about what happens in online discussions. However, adding microethnographies, conversation and discourse analysis techniques to our repertoire provides a more robust look at how the participants in the overall conversation are participating in a process of knowledge creation. By looking at the function that their posts serve in a larger context, meaning making is revealed.

CONCLUSION

In closing, research into online conversations in educational settings should be looking more thoroughly at how groups of learners are engaged in contextualized discourse. As a discipline, distance learning is in need of a rigorous research framework with solid epistemological grounding that will encourage comprehensive study of how learning takes place through group interactions on a discussion board. Such a framework will need to account for all types of participation or learning processes (internal and external, individual and group). It will need to promote data collection beyond just downloading post-course archives of discussion threads in order to capture contextual factors that impact ecological validity. Stahl's social theory of computer-supported collaborative learning may provide the necessary theoretical underpinnings to support the development of a new paradigm of online discourse research, one that looks to methods such as microethnography and conversation and discourse analysis in addition to more traditional participation, content and structure oriented methods.

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Making a Mesh of It: A STELLAR Approach to Teacher Professional Development

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Abstract. We propose a model for Internet learning grounded in a theoretical analysis of transfer and embodied within a general tool called STELLAR (Socio-Technical Environment for Learning and Learning-Activity Research). STELLAR supports creation and management of online courses that systematically integrate collaborative design with study of text and video. The objective of STELLAR is to help learners develop "meshed" cognitive representations that support transfer of course knowledge to professional practice. Using STELLAR, we created experimental online courses in the learning sciences[1] for pre-service teachers. Our research produced substantial evidence supporting our approach and a body of empirically tested online materials and collaborative activities for teacher education.

Keywords: Teacher education, transfer, online learning, instructional design, problem-based learning, design-based learning, video cases

INTRODUCTION

There is substantial evidence, summarized in publications sponsored by the US National Academy of Education (Bransford, Derry, & Berliner, in press) and US National Academy of Science (Bransford, Brown, & Cocking, 2000), that when educators base instructional decision making in discipline-appropriate learning sciences, students of all ages and abilities are more likely to acquire deeper, more meaningful, more useful understandings. However, although virtually every program of teacher education "covers" learning-sciences subject matter in one or more courses, research shows that knowledge acquired during teacher preparation is used by teachers in limited and naïve ways (Darling-Hammond & Sykes, 1999; Weiss, Pasley, Smith, Banilower, & Heck, 2003). Moreover, evidence from multiple disciplines shows that transfer of training from classroom to practice is very difficult to achieve (Gick & Holyoak, 1980; Lave & Wenger, 1991; Salomon & Perkins, 1989). Thus, an important question motivating our work is how to design learning environments that can feasibly be implemented on a large scale and that will help teachers acquire *useful* learning-sciences knowledge from their teacher education programs.

We are especially interested in learning how to exploit the power of Internet technology for "scaling up" good professional development. Instructional approaches with new media can enhance transfer, accelerate learning (Spiro, Collins, Thota, & Feltovich, 2003; Spiro, Feltovich, & Coulson, 1992), and create more seamless connections between formal learning environments and professional practice (Fischer, 1998). Although online graduate programs for educators are proliferating, we believe most current models fail to address the changing demands of professional practice. Like Fischer (2003), we argue for educational programs that encourage students to be life-long, reflective learners who employ new media to conduct research and collaborate with others to solve problems. Unfortunately, most Internet educational programs too closely mimic traditional instructional forms; that is, they are technologically "gift wrapped" (Fischer, 1998) versions of traditional knowledge-delivery systems, too removed from professional practice.

[1] *Learning sciences* refers to current scientific and theoretical knowledge about students' learning and development in formal and informal learning settings.

Our alternative to technology "gift wrapping" is a method embodied in a system we have built to support online course design, development and management. Called STELLAR (Socio-Technical Environment for Learning and Learning-Activity Research), this system contains tools to build and manage courses that systematically integrate study of text with study of digital video cases of student work and teacher professional practice, and with activities in which teacher-learners collaborate in creating and critiquing designs for their own practice. The types of assessments that STELLAR courses are intended to impact are evaluations of authentic teacher work, such as justified lesson designs.

In the next section we will elaborate further on the theoretical basis for our instructional design approach, including its connection to and difference from other instructional design theories. Next, we will describe a course that was built and managed in STELLAR and offered over several years in two different university settings. We will show empirical evidence regarding course effectiveness. Finally we will discuss the new directions in collaborative learning research that our future work will address, including some reflections on the future of CSCL as a field of study.

THEORETICAL RATIONALE

The STELLAR approach can be framed in terms of what Salomon and Perkins (1989) and other cognitively-oriented researchers (e.g., Schwartz & Bransford, 1998) call *the transfer problem*. STELLAR courses attempt to scaffold students in developing *transferable* representations of course ideas -- learning-sciences concepts and skills in this example. An important stage of transfer occurs when, during professional practice, there is spontaneous and situation-appropriate activation and use of complex knowledge systems that incorporate course ideas. We call those knowledge systems *schemas,* in the tradition of (Bartlett, 1932). The goals of STELLAR courses include helping students develop schemas that will promote spontaneous transfer of course ideas and that will serve as a basis for "professional vision" (Goodwin, 1994), future professional discourse, and continued learning.

We believe that the schemas that STELLAR online learning environments help students acquire are characterized by a high degree of *mesh* (Glenberg, 1997) among the *concepts* and *skills* taught by a course, *perceptual visions associated with cases of practice,* and *plans for* acting in the professional setting. Although the concept *mesh* is very important to our theory, there is not space in this presentation and it is not the purpose of this paper to develop a model of the specific cognitive processes underlying *mesh*. We will state only that we use the term in two ways: 1. we see mesh during the learning process if there is evidence in work or discourse that students make connections between two or more ideas or perceptual experiences; and 2. we assume that repeated meshing of ideas and perceptions during learning promotes cognitive representations that reflect that mesh. So, we speak of seeing mesh in classrooms and on line (Hmelo-Silver, Derry, Woods, DelMarcelle, & Chernobilsky, this volume), and of learning outcomes as cognitive representations (e.g., schemas) that mesh perceptions and ideas.

STELLAR courses are "high-mesh" courses. They attempt to engineer mesh among forms of knowledge (concepts, skills, perceptual encodings of cases, and plans for doing). This is accomplished through carefully designed learning activities that scaffold students as they systematically and repeatedly bring together course ideas garnered through text study, visions of practice gained from video case study, and planning knowledge gained from facilitated collaborative lesson design. The point is to create meshed memories that automatically and flexibly activate one another, in professional settings that are similar to (but not exactly alike) those that are encountered through problem solving and case study in college courses.

However, transfer to future practice is not just *spontaneous* and *automatic* activation, for practitioners must also *adapt* to situations and continue to learn from resources available in their professional environment. Thus teachers must not only spontaneously activate previously learned course ideas and plans in response to events in their practice, but they also must respond by using course knowledge to help them take an evaluative and reflective stance on their work. Thus STELLAR courses also aim to help future teachers develop skills and tendencies needed to consider different situational interpretations, and to recognize when situations are in some sense new and thus require additional knowledge and alternative plans of action.

Relationship to other instructional design theories

Our view of transfer is related to Cognitive Flexibility Theory (CFT) (Feltovich, Spiro, Coulson, & Feltovich, 1996; Spiro et al., 2003; Spiro et al., 1992; Spiro, Feltovich, Coulson, & Anderson, 1989; Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987). A CFT analysis suggests that teaching is an ill-structured domain in which practitioners must learn to flexibly assemble a multiplicity of concepts, including pedagogical concepts (how to teach), disciplinary concepts (e.g., biological concepts such as *adaptation*), and learning-sciences concepts (e.g., how students learn through collaboration) as appropriate in different situations.

Our approach also shares connections with case-based reasoning (Kolodner & Guzdial, 2000). We build on the notion that, in many ill-structured domains without a strong causal, mechanistic underpinning, knowledge is organized around cases. A case representation includes a problem, the solution, and the evaluation of that solution. One can reason about cases that represent both successful and unsuccessful solutions. Case-based reasoning suggests that when we have a problem, we use our knowledge of previous cases to help point us toward helpful solutions and to help avoid ineffective solutions. Similarly, we suggest that for transfer to occur from the college classroom to the teacher's own classroom, the teacher needs a foundation of conceptual knowledge that is meshed to a base of case knowledge.

Our view of transfer is also consistent with Schwartz and Bransford's (1998) notion of preparation for future learning, the idea that transfer includes the capability to adapt and learn from new situations. When actions produce outcomes, teachers must determine if outcomes were the desired ones and what actions to take next. If outcomes are unexpected or problematic, a "breakdown" has occurred that requires creative problem framing and a search for relevant knowledge (Fischer, 1994). Thus teachers must be reflective practitioners and a course should help them become that. That reflection is an important stage in professional learning is the basis for the well-regarded reflective practitioner model (Schön, 1983) and all major cognitive models of self-regulated learning (Azevedo, Guthrie, & Seibert, 2004; Pintrich, 2000; Winne, 2001).

Differences from other theories

Our thinking has evolved beyond CFT in several respects. For one, we have been explicit regarding some specific forms of knowledge that should be meshed together into schemas during instruction. For teacher preparation in the learning sciences, these include: 1) both declarative (e.g., what is scaffolding?) and procedural (e.g., how do you scaffold instruction?) knowledge of the learning sciences; 2) perceptual visions of classroom practice that represent general cases that are likely to be seen in future; and 3) planning knowledge, both component instructional activities and general planning skills. The planning approach we have taught in our STELLAR courses are strategies for goal setting, assessment, and instructional activities (Wiggins & McTighe, 1998).

Our theoretical position also differs from case-based reasoning in important ways. Regarding knowledge representation, we do not believe cases are maintained intact in memory; rather, we believe that memories of particular cases fade with use and over time and that case memories become meshed together with other similar cases. We believe that experience with many cases over time can build on the schemas developed in courses, shaping and updating and abstracting them in important ways (Derry, 1996). A purpose of professional courses is to develop foundational schemas that will evolve during future learning.

Finally, as we plan our future work, our theoretical position is evolving away from reflective practitioner models that focus primarily on developing the individual, self-regulated learner. Learners in STELLAR courses not only work and learn as individuals, but also are scaffolded to engage in and acquire reflective collaborative practices within socio-technical environments that distribute knowledge over people and technology-based tools. We have more to say on this topic in the last section of our paper.

AN EXAMPLE COURSE ACTIVITY

The STELLAR system provides tools for helping course developers and researchers create and manage online student-centered collaborative learning activities that intertwine text and video case study with design activities. Although many different course and activity designs are possible, one example of a course activity built with STELLAR is provided. This activity was part of the eSTEP (Elementary and Secondary Teacher Education Project) course, a teacher preparation course in learning sciences that has been offered at both UW-Madison and RU since spring, 2001. The eSTEP course materials are housed in a website (created with STELLAR) that integrates three components: a Knowledge Web (an online learning-sciences hypertext book); a video case library that is thematically intertwined with the Knowledge Web; and PBL online, a collection of facilitated small-group lesson design activities that follow a PBL format (Barrows, 1988; Hmelo-Silver, 2002). A typical eSTEP course consists of several 2-3 week segments in which participants intensively study video cases and text to acquire "perceptualized" conceptual knowledge about learning sciences. They also engage in instructional design activities that integrate this knowledge with planning for future practice.

For instance, in Fall Semester 2002 at UW-Madison, pre-service teachers were guided through an eSTEP instructional activity by the toolbar presented in Figure 1.

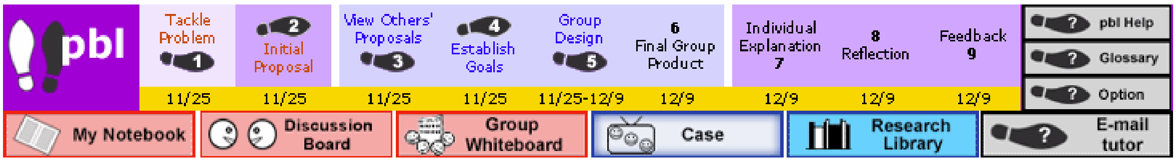

Figure 1. eSTEP task bar

In Step 1, participants signed on and read their PBL problem, a group assignment to design a "bridging instruction" lesson for a mathematics concept of their group's choice. "Bridging instruction" is a complex pedagogical idea taught in the eSTEP course. To prepare, the pre-service teachers first read about bridging instruction in the Knowledge Web and studied an online video case depicting a bridging instruction lesson taught by an experienced teacher. As students studied the case, they followed links into the Knowledge Web that provided guidance in case analysis. In Step 2, participants used online personal notebooks to develop a case analysis and an initial lesson idea. This work was shared and discussed with group members in Step 3. In Steps 4–6, groups used a backwards-design strategy (Wiggins & McTighe, 1998) to complete a lesson design, an activity supported online by a STELLAR tool, the *group whiteboard* (Hmelo-Silver et al., this volume), which facilitates group design and decision-making (Figure 2). In Step 7 and 8, students submitted individual critiques of their group design and reflected on their learning, collaboration, the design of the lesson itself, and the usefulness of their designs for their own practice. As instructional designs evolved over the course of the PBL activity, they were reviewed by online facilitators, who offered ongoing formative help to individuals and groups. An analysis of the online PBL process is found in Chernobilsky, Nagarajan & Hmelo-Silver (this volume).

FROM ESTEP TO STELLAR.

Although the UW and Rutgers implementations of eSTEP share many similarities, each course serves different populations of preservice teachers and must be adapted to work in their respective contexts. These differences provided a reason and opportunity to build STELLAR, a general system that embodies our theoretical principles and can be adapted to different contexts and teaching subjects. STELLAR provides tools to support instructional designers, facilitators and researchers. For instance, course designers can use STELLAR to select and adapt tools and interfaces (e.g., the group whiteboard, Figure 2), and combine them into new activity structures, such as the PBL activity for math education students. STELLAR facilitates uploading of and presentation of videocases in multiple instructional formats, such as contrasting cases formats (e.g., Schwartz & Bransford, 1998). Hypertext environments can be developed within STELLAR and can be integrated with the video case library. This flexibility allows researchers to create and manipulate instructional designs and test theories about cognition and instruction. Likewise, STELLAR has an interface for online facilitators, which they use to access all participating learners' work, and to interact with individual learners or entire groups. This provides opportunities for powerful and frequent formative assessment. Once a course is complete, researchers can use STELLAR interfaces to access summaries of student work and to retrieve a variety of log files, including statistical summaries of Likert-scale feedback on the tools and activities used in a course. STELLAR products are extensible as well, so eSTEP materials can be added to and used in other professional development contexts.

RESEARCH STUDIES

Data sources and scoring

In addition to students' ratings of tools and activity steps, our experimental eSTEP course offerings have typically produced the following categories of data: 1) Group instructional plans developed online during PBL activities; 2) Online group discourse during each PBL activity; 3) Individual reflections, adaptations, and analyses from PBL activities; 4) Pre- and post-course analyses of teaching/learning video cases; 5) Pre- and post-course self-reports of beliefs and attitudes related to teaching and learning; and 6) Log data that can be analyzed to determine individual patterns of use of Web-site tools and learning resources.

To evaluate the work in Items 1–4 above, we developed *concepts-in-use* rubrics for judging and scoring pre- and post-video analyses and other student products in order to measure the level of sophistication manifest in students' spontaneous (students were unaware of rubrics) embedded uses of target learning sciences concepts, such as *understanding*, *metacognition*, and *transfer*. All rubrics in our research are being designed for use across multiple types of learner products, documents, and classroom performances. All include features to help coders determine what to focus on when judging learners' work, and all are calibrated to a single scoring scale. The psychometric properties of the rubrics are being assessed and improved through validity and reliability studies.

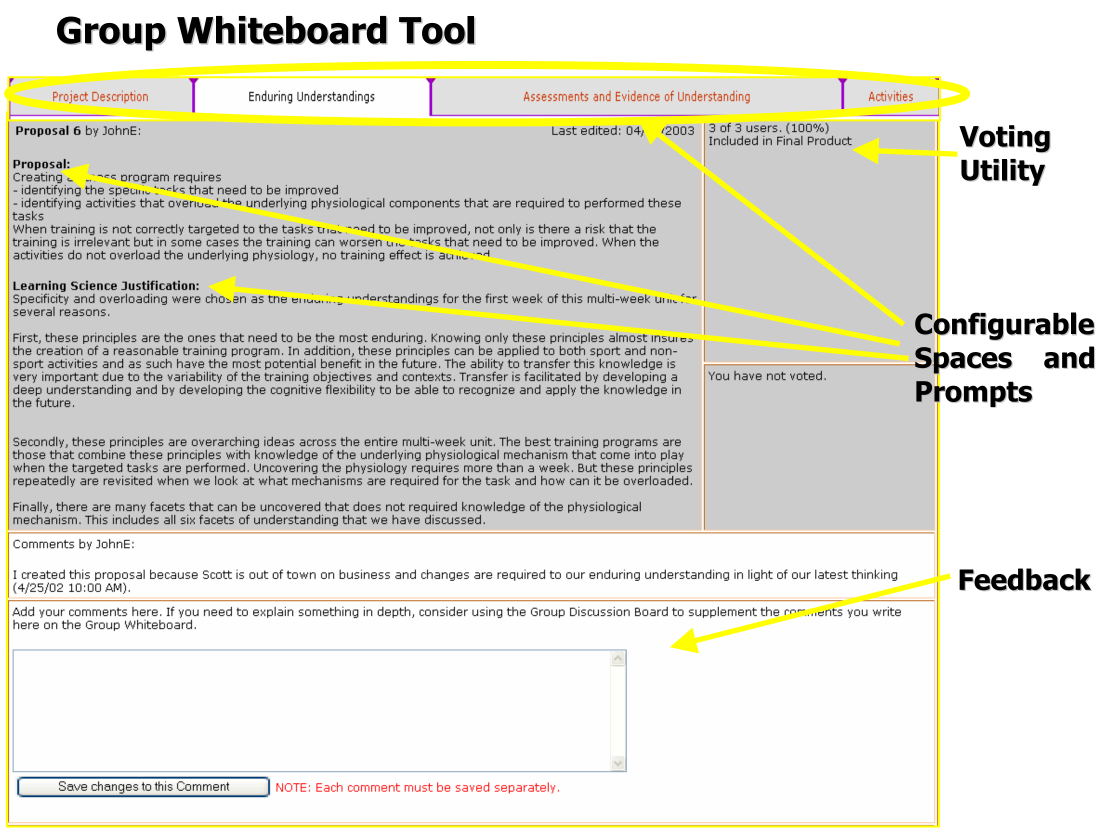

Figure 2. STELLAR whiteboard

As an example, the features of our rubric for the concept *understanding* and the scoring scale to which it is calibrated are shown in Tables 1 and 2. Inter-rater reliabilities for this rubric in repeated uses have consistently exceeded .90.

Table 1
Features considered in judging ability to use the concept understanding in planning and analyzing instruction

Points are not awarded for use of the term *understanding*. Judge whether products or explanations explicitly or implicitly represent knowledge that:
1. Understanding is actively constructed knowledge. 2. Understanding builds on prior knowledge. 3. Understanding in context is an active process of comprehension that involves constructing a situation model. 4. Understanding supports the making of inferences and/or application in new contexts. 5. There are different depths or forms of understanding. 6. Understanding involves grasping the underlying principle, theme or big idea. 7. Understanding is socially negotiated and distributed in *communities of practice* (broadly defined to include classrooms and groups).

Table 2
Scoring scale

0 "Knows nothing." Observations or products contain no evidence that any aspect of the concept is understood or attended to, or there is evidence that the concept is rejected or not understood. The concept is very unlikely to be used correctly in planning or implementation unless the student teacher receives and is open to *intensive assistance.*

1 "**Needs substantial scaffolding**." Observations or products indicate that there is some limited understanding and acceptance of the idea and that a limited range of acceptable implementation of the idea is occurring. However, there are major omissions, weaknesses, or misunderstandings in relation to the idea and the student teacher will probably need *substantial assistance* to help him or her use the idea successfully.

2 "**Demonstrates early expertise**." Observations or products indicate the idea is likely understood with some range and depth and is being implemented with at least moderate success as conceptualized. However, there are some weaknesses or omissions that should be addressed, and this part of the student teacher's work could be improved in important ways with *some assistance.*

3 "**Expert**." Observations or products provide evidence that the idea is well conceptualized in depth and detail and over a range of uses and is being implemented successfully and reflectively with sophisticated understanding, even though improvements might still be possible. Encouragement and positive feedback but *little assistance* would be appropriate.

Study 1: Evaluation of 2002 course offerings at two campuses

Student evaluations

Students' evaluative ratings of the online activities overall, specific steps in the activities, and the system tools used in implementing the activities online, were generally positive, ranging from 3.78 to 4.52 on a five-point scale. The data indicated that students favored collaborative over individual steps in the learning activity.

Although a few students' comments reflected a struggle with technology (this type of comment is becoming less common with increasing availability of high-speed Internet connections), characteristic quotes from students, taken from their reflections about the experience (steps 7 and 8), were positive.

- *. . . this lesson that we have designed as a group is definitely something I could see myself using down the road when I have my own classroom. I feel it is a well thought out lesson that can be easily modified to meet the needs of whatever type of class "make-up" that I may have.*
- *The plan that we made up as a group will be something that will be extremely useful for me as a teacher. I also learned the value of input from others' viewpoints on the same unit because you are able to see different perspectives that can give you some new and different ideas.*

Learning outcomes and correlates.

Table 3 shows mean scores from students' pre- and post-course video analyses, based on the *'understanding of understanding'* rubric previously described. Essentially, these means reflect gains in the college students' abilities to apply their psychological knowledge about the cognition of understanding to carry out a critical analysis of videotape of classroom teaching and resulting student performance. This is an important outcome variable, and the gains made in the eSTEP courses were substantial and meaningful in two contexts.

Table 3
Pre- and post-course "understanding in use" means and standard deviations (in parentheses) for UW & Rutgers

	UW	**Rutgers**
N	N = 60	N = 33
Course Level	Learning Sci taken in last year of Teacher Ed	Ed Psy prerequisite for entering Teacher Ed
Pre-course score	Mean = 0.65 (.46)	Mean = 0.42 (.55)
Post-course score	Mean = 2.09 (.63)	Mean = 1.56 (.63)

We conducted exploratory stepwise regression analyses with these same data to help generate hypotheses about possible relationships between college students' experience in the online environment and their actual learning outcomes (based on the understanding score), as well as their *perceptions* about how much they learned (based on an overall self-report rating). In the first analysis, the "understanding of understanding" score was the dependent variable. Predictor variables allowed to enter into the regression equation were various "successful tool use" indices, which included students' ratings of system tools and other data on system use, such as number of times a student logged on. The set of independent variables that best predicted successful performance on the video analysis, scored with the understanding rubric, were: a) entering pretest performance; b) site (Rutgers versus UW); c) positive ratings of the group whiteboard for collaborative online design; d) positive ratings of links between video cases and the KWeb, which scaffolded video viewing; and e) overall number of Web hits (R^2 = .38). However, when self-reported *perceptions* of learning (e.g., students' ratings of how much they believed they learned) was the dependent variable, the best predictors were success scores with tools and resources that were designed for individual study (R^2 = .42). A strong predictor was successful experience with the KWeb, which was designed in accordance with cognitive flexibility theory (Spiro et al., 1992) and was often used by individual students to explore personal interests.

We also conducted a factor analytic study in which items from a pre-course questionnaire were factored with the understanding score. At both sites, "understanding of understanding" loaded negatively with items comprising a factor that seemingly measured a belief that the cause of learning is primarily external context. A person holding this 'contextualist' point of view would tend to respond "strongly agree" to an item such as "teachers (or the home environment) are the main determinants of student learning." From this finding, which was consistent in separate analyses across two sites, we hypothesized that helping college students develop an appreciation of the role of cognitive processes in teaching and learning may require challenging strong incoming beliefs that only contexts external to the child are responsible for success in school. We hope that teacher-learners leave our course with an alternative view, that learning environments are complex systems involving coordination of both internal and external factors.

Study 2

A study conducted at Rutgers in 2004 compared performance and gains in the eSTEP course to performance and gains of students drawn from multiple traditionally-taught lecture courses of approximately the same size and student population. (Because the eSTEP course at UW-Madison is taught as an advanced course to the entire secondary education cohort, no similar comparison course for the same student population exists at UW-Madison.) Since the instructors differed for these two courses, results must be interpreted with caution. Nevertheless, based on scores derived from a video analysis task and the understanding rubric previously described, there was a statistically significant difference in final performance and performance gains, favoring the eSTEP course (ANCOVA F (1, 67) = 69.62, $p<.001$). Results are displayed in Table 4.

Table 4
Comparison of eSTEP with traditional course

		N	Mean	Std. Dev
Pre	**eSTEP**	32	.97	.55
	Comparison	37	.93	.50
Post	**eSTEP**	33	1.92	.77
	Comparison	37	.78	.48

CONCLUSIONS

In summary, we have accomplished the following:

- Developed a theory-based model that is feasible for online instruction on a large scale and that addresses a continuing major problem: the failure of most college classrooms to teach conceptual content in ways that insure its use in students' future professional lives. Our approach integrates text-based instruction with video study and authentic problem-based learning (PBL).
- Developed extensive online video, text materials, instructional activities, and online tools for supporting this instructional model to teach learning sciences to future teachers. The materials and tools are available through eSTEPWeb.org (a password protected site because of human subjects regulations regarding online uses of classroom video). They include the eSTEP Knowledge Web, an online multimedia textbook on learning science, an integrated (with hypertext) video case

library, and a system for setting up and managing collaborative problem-based learning activities on line.

- Using the resources above, we designed, offered, and tested innovative, experimental online learning science courses for pre-service teachers, demonstrating the effectiveness of our approach in variations adapted to two contexts. This entailed developing theoretically valid and psychometrically sound rubrics for scoring student work collected from eSTEP courses, which can be generalized to evaluation of teaching beyond the current project.

In addition, we believe the following:

- STELLAR designs produce significant increases in teacher-learners' abilities to think deeply about student understanding in analyses of realistic video cases of teaching and learning.
- A STELLAR "high-mesh" course was more effective at producing transfer than a traditional lecture-based approach covering the same material, although the non-experimental nature of this research requires a conservative interpretation.
- The STELLAR suite of online instructional tools can be combined in designs to produce effective instruction. The group whiteboard, which was configured to scaffold collaborative online lesson design, was an effective tool.
- In STELLAR courses, performance on a targeted instructional goal was moderately correlated with variations in site context and with successful use of tools that scaffold collaboration. However, students' *perceptions* of how much they learned were more dependent on successful use of tools that aided individual exploration.

We acknowledge that there are some limitations in the work we have reported here. There are many improvements to interface design that might be accomplished given adequate time and funding. We recognize that we have not conducted experimental studies to prove the effectiveness of our approach. And although we have developed some authentic assessments, we have not studied the impact of our course design on actual teaching practice, much less on how that practice affects K-12 student learning.

And yet our work so far represents a pioneering step in an emerging science of web-based course design that is informed by cognitive theory and that blends online video case study with collaborative problem solving. We continue to improve our general tool (STELLAR) that will allow researchers and developers from any discipline to design, offer, and monitor "high-mesh" courses and activities representing variations on our model.

FUTURE DIRECTIONS AND REFLECTIONS ON THE FUTURE OF CSCL

We envision a socio-technical future for teachers, one that helps empower them as professionals and as agents for social change (Gutiérrez, 2002). Developing teachers who can move into that future is part of our agenda now. Developing new theories of learning, new models for teacher professional development (TPD), and new socio-technical environments that support teachers as lifelong learners within communities will be major themes in our future work.

In the US, teaching is one profession where there is little opportunity for collegial interaction during the typical workday (Ball & Cohen, 1999; Lieberman, 1996). Yet situative theorists conceptualize individuals' use of knowledge as an aspect of their participation in social practices (Greeno, 1998; Lave & Wenger, 1991). Putnam and Borko (2000) argue that professional development must attend to both individual teachers as learners and as participants in professional communities. It is not surprising that collaborative Web-based technologies and professional Web sites are increasingly embraced by teachers as important forms of support for building professional community.

Online community approaches to continuing TPD, including graduate education, are often founded by non-profit groups with particular agendas. An example in the US is Wisconsin's Mathline (now Teacherline). Mathline was initially funded in 1995 through a Department of Education grant to the Public Broadcasting System and in Wisconsin grew over the intervening 10 years into a PK-16 statewide teacher professional development network. Mathline followed what Smith (2001) and others call a practice-based model of TPD (Ball & Cohen, 1999; West & Staub, 2003). In this model, online dialog among participating teachers is grounded in concerns of professional practice, and discussion of the organizing group's objectives occurs after teachers are comfortable discussing their own work (Grossman, Wineburg, & Woolworth, 2001). Trust is a crucial ingredient, and creating such trust is not easy. Mathline's strategy was to find facilitators who were recognized by their peers as master teachers, and to support these master teachers with extensive training in online facilitation (Collison, Elbaum, Haavind, & Tinker, 2000; Fullan, 1999; Lieberman, 1996). An initial study of Mathline dialogue suggested that fully half of the community's discourse was unplanned by facilitators and driven directly by the immediate needs of practicing teachers. Professional learning communities integrate the day-to-day concerns of teachers with the course's main themes.

Given existing models to build on, it does not require a giant leap of faith to envision a future in which TPD communities might operate as self-sustaining socio-technical systems that integrate formal, informal and work-related concerns and that engage in meaningful collaboration, social creativity, and problem framing around socially important issues (Fischer, 2002). Achieving this vision and developing theory to support this achievement are goals we embrace for our future work. Our approach will involve building on existing success models in an attempt to design new STELLAR graduate courses that will seed facilitated online professional communities for teachers and that will continue to attract them as participants beyond the life of the course. In the socio-technical communities we envision, teachers will continue to work and study together to further their knowledge and involvement in the very themes (for example, teaching mathematics for social justice) that attracted them to enroll. However, it is not only our vision that counts, for what we hope will emerge from this effort is a co-evolving system: a reflective community that is capable of deciding for itself what it is, including the ability to adapt its socio-technical environment to meet its changing needs. The socio-technical environment and organization must itself support this, incorporating strategies to encourage continuous reflection and problem solving. This is one version of what Fischer and others have called the science of *meta-design* (Fischer & Giaccardi, 2004), a process that involves "seeding" communities using basic "reusable" socio-technical designs that are adapted to each community's needs. We think this is an important concept for our future work with teachers and an interesting topic for the CSCL research community to address.

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Designing Collaborative Learning Systems: Current Trends & Future Research Agenda

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Abstract. The research community, in order to support learning as well as collaboration, has designed systems, which, distinctive from common web-based ones (simply enabling collaborative activities), constitute new cognitive and meta-cognitive tools. The paper proceeds with a categorization of the main tools and functions that characterise collaborative learning systems (designed for primary/ secondary/ higher/ education) in order to discuss the current trade-offs. It proposes a design framework for collaborative learning systems that are addressed to primary & secondary education. This framework is derived from considerations of cognitive psychology, science education, and CSCL community research results. The paper concludes by presenting the main themes of the actual research agenda, which is intended to help design systems that can be integrated into primary and secondary education contexts.

Keywords: Collaborative learning systems, primary / secondary education, trade-offs, framework

INTRODUCTION

The Computer Supported Collaborative Learning (CSCL) community works on theoretical frameworks, tool and artifact design, appropriate architecture and development approaches as well as various methods for a significant qualitative and quantitative evaluation of collaborative situations. The community also deals with the implementation of actual educational systems, collaborative learning activities and new pedagogical approaches, while seeking new roles for various implicated agents (i.e. students, teachers). Ultimately, it aims at: (a) producing tools and systems, (b) developing our understanding of learning processes and (c) finding the best ways to implement new approaches and tools into actual educational systems. The reader may find significant review papers exploring the evolution of research on collaborative learning (Dillenbourg et al 1996), the meaning of collaborative learning (Dillenbourg 1999), the epistemological foundations of CSCL (Lipponen 2002; Paavola et al, 2002) and learning effects and best practices (Lehtinen et al, 1998). All of these topics have been the subject of theoretical reviews and foundation papers.

However, many questions remain unanswered. "What are the *main design achievements* of this research field?" "What are the *current trade-offs* and what are the various designers' choices concerning significant design aspects?" "What are the main *actual design questions* that preoccupy researchers and form the *research agenda* for upcoming years?" The exploration of these general questions serves as the objective for the present paper.

There are many ways to promote collaborative learning: gathered around the computer, through new technological gadgets, through a balanced combination of the various tools existing on the web, etc. In this paper, we have based our analysis and discussion of collaborative systems on those that have been explicitly designed for learning purposes and concern a wide range of learning activities for primary, secondary or higher education. The paper proceeds to present a categorisation of the main tools and functions that characterise collaborative learning systems so as to discuss the current trade-offs. In order to synthesize the new design trends of collaborative learning systems that are addressed to primary or secondary education, a framework of analysis is proposed. This framework is derived from considerations of cognitive psychology, science education, and the CSCL community research results, while also taking into account the social context of the school. Finally, the main axes of the actual and future research agenda are pointed out.

TRADE-OFFS ON COLLABORATIVE LEARNING SYSTEMS DESIGN

Before discussing the means for supporting collaboration, it would be useful to categorize collaborative learning systems according to the kind of collaborative activities that they each support, given that the main means of dialogue and actions that students dispose depend on the learning activity itself. In general, existing systems can be divided into two main categories:

(a) *Action-oriented collaborative systems*: Some collaborative systems are based on the idea of starting from a student's actions, expressing and capturing the student's emerging knowledge and then making this knowledge-representation itself a subject of artifact-centered discourse. This is the case, for instance, of action-oriented systems based on disciplinary representations, including those of C-CHENE (Baker & Lund, 1997), COLER (Constantino-Conzalez & Suthers, 2001), COMET (Soller 2002), Cool-Modes (Hoppe & Gabner, 2002), Algebra-JAM (Wu et al. 2002), CoLab, (van Joolinger, et al., in press), MODELLINGSPACE (Dimitracopoulou & Komis 2004), as well as Convince Me (Ranney et al, 1995) and SenseMaker (Bell, 1997). In most of these systems, the underlying learning activities are mainly based on synchronous communication.

(b) *Text-production oriented systems*: This category of collaborative systems invites students mainly to produce a written text or report in a collaborative or cooperative way. For instance, in Knowledge Forum (Scardamalia & Bereiter, 1994; Hakkarainen & Lipponen, 1998), CoVis (Pea et al, 1994) or Fle3 (Leinonen & Kligyte, 2002), students have to create text-based files presenting their point of view on a topic or report on a whole activity. This constitutes the principal activity addressed to wide groups that are focusing on building their shared knowledge and developing into a community of learners. Also belonging in this category are those systems supporting collaborative argumentative writing, such as COSAR (Erkens et al, 2002). In most of the systems of this category, the underlying learning activities are mainly based on asynchronous communication.

An analysis of the existing collaborative systems shows that a number of tools and functions are designed and implemented in order to facilitate or better support the collaborative learning process. In order to discuss these in a brief way, we have viewed them through the lenses of their support for the specific *high-level functions* that should be performed during collaboration:

(A) The appropriate means for dialogue and action: They provide the essential means for the collaborative learning activity itself.

(B) The functions for workspace awareness: They are related to up-to-the-minute knowledge about partners' actions in a closed collaborative scheme or in a wide community of collaborators.

(C) The functions for supporting students' self-regulation or guidance: They support or directly guide students' reasoning on a metacognitive level.

(D) The facilities related to teachers' assistance: They are essential, especially when the systems are addressed to students of primary and secondary education.

(E) The functions related to community level management: They provide significant tools and functions for management of the activities and material produced amongst a wide community.

One central aspect of work in CSCL involves concerns over design trade-offs. Anything designed is, usually, only one choice among many possibilities that were considered as well as even more possibilities that were never considered. Therefore, why is a focus on trade-offs important? Because much of the critical discussion centering around collaborative learning takes an extreme position on one or two dimensions of the design trade-off, overemphasizes those dimensions at the cost of acknowledging the most basic point that trade-offs are inevitable in design.

Let's consider some important trade-offs in thinking about the design of collaborative environments. Currently, the main trade-offs (that is to be) considered by designers are related to the principal functions of CSCL systems mentioned above:

(1) The means of dialogue (an always-crucial aspect in collaborative learning) deals with at least the following three specific trade-offs: (i) between free and structured dialogue, (ii) between parallel and embedded communication tools (iii) and that between text-based and oral dialogue tools;

(2) The trade-off related to the coordination of action versus dialogue (influencing the students' freedom);

(3) The trade-off between metacognition support for self-regulation and teacher support;

(4) The more general trade-off related to designing an action-based system or a system based on text production (that could influence the new tendencies of a system's main features).

Trade-offs Related to the Means of Dialogue

Systems, either action-based or text-based, and even if they dispose a shared workspace to the collaborators, all provide one or more dialogue tools. These means are considered crucial not only for collaboration but also for learning. Externalization achieved through written dialogue that is conducted during collaborative activities may have significant effects, especially for conceptually rich learning activities (e.g. those related to science or mathematics). Interactive linguistic exchanges among people play an essential role in the elaboration and perpetuation of scientific concepts, while the primary use and mechanism for acquisition of these concepts is the result of social interaction.

In designing the means of dialogue in a learning environment that supports synchronous collaboration, one has to deal with at least the following three specific trade-offs between: (i) free and structured dialogue, (ii) parallel and embedded communication tools, (iii) text-based and oral dialogue tools.

The Trade-off Between Free and Structured Dialogue

The related discussion mainly concerns the eventual choice between conducting a free chat or a structured one in synchronous collaboration mode and it is also related to the possibility of design-threatened forums or chats.

Let's consider the case of synchronous collaboration. A principal-related designer's question is highlighted by the choice between a free chat interface and a structured dialogue interface. Such a question must be examined by looking at what conditions and for what task users may need each function. Research results show (Baker & Lund, 1997) that pairs who use the 'free' communication mode more than the 'structured' one produce more 'off-task' statements than those who prefer the 'structured' mode. However, we could hypothesize that the appropriateness of a free versus structured interface is not independent from the type of content being uttered. For example, the free chat interface that allows unstructured, synchronous dialogue, seems to be more appropriate during the initial brainstorming phase of problem-solving, the discussion on problem-solving or modeling strategy, eventual decisions regarding task distribution among different members, etc. It seems that management of the problem-solving process or of a project elaboration is more often expressed by using the free section, while the structured one more often expresses task and strategy contributions. In all cases, the interest of the designers of dialogue tools aimed at promoting collaborative learning is deepening the space of debate and producing *epistemic interactions* (Baker et al, 2001). This ultimately feeds argumentation, particularly that which occurs at a conceptual level and can stimulate reflection on subjective explanatory systems (Baker et al. 2003).

Related to the appropriateness of structured chats, there are objections that we must have in mind when designing CSCL environments: (a) Practitioners believe that if the participants of a collaborative learning situation could choose between a structured communication mode and a 'free' communication mode, they would definitely choose the latter. But, some experiments (Jermann, 1999; Baker & Lund, 1997) have shown that the structured section of the interface was more frequently used than the free section. (b) Requiring learners to select a sentence opener before typing the remainder of their contribution may tempt them to change the meaning of the contribution to "fit" one of the sentence openers, thus changing the nature of the collaborative interaction. For this reason, it is critical that the sentence openers enable the widest possible range of communications with respect to the learning task (Soller, 2002). (c) Finally, it is to be noted that, besides the gains that learners may have achieved through a structured dialogue, this dialogue is also crucial for realizing the benefits of a significant meta-analysis of collaborative activity, constituting another advantage of a structured interface. However, the sentence openers are not always used as intended, resulting in subsequent contributions that would not necessarily correspond to the discussion skill represented by the sentence opener (Dillenbourg, 2002). This is something that we must have in mind if the corresponding data is processed for analytic purposes.

In the case of asynchronous or even synchronous dialogue, another kind of structured dialogue tool to be considered is a *threaded discussion,* or *tree structure,* that may be viewed in a summary form. This kind of structure is created just after each dialogue statement (e-mail, chat, forum) is entered, thus there's no need to intervene in the students reasoning during conversation.

Up to the present, a number of dialogue tools have been developed, forming a broad spectrum of possibilities, from the unstructured to the structured and onto the abstract (e-mail, chat, threaded forum, structured chat, post-it annotations, concept maps, specific representation formalisms, etc.). Recent research has explored the differences between students working only with an on-line chat and those working with a chat and a graph dialogue tool (Baker et al., 2003). The results showed that students who had both a chat and a graph dialogue tool at their disposal produced more arguments than their counterparts.

The trade-off, in terms of design, can be resolved by the simultaneous support of a wide range of dialogue tools offered to users. We consider that it is important to provide students with multiple tools of dialogue, to assure flexibility of use for different instances and according to the apparent needs of different phases of collaboration as well as according to the needs derived from the specificity or the complexity of the task.

The Trade-off Between Parallel and Embedded Representations and Tools for Dialogue

A recent trade-off has appeared between the "parallel tools" and the "embedded tools" for dialogue, especially apparent when users work in action-driven systems. Most of the existing systems offer shared artifacts and discussion tools on entirely separate windows. This seems to lead to a disjointed discourse about the artifacts, even if one can work around this problem by placing the discussion tools next to the artifacts under discussion (Reeves & Shipman, 1992). D. Suthers refers to these as *parallel communication tools:* defined as tools that do not assure any coordination between the discourse and disciplinary representations (Suthers, 1999). In cases of separate artifacts, there is a greater distance between the object of the discussion and the corresponding dialogue, hence the cognitive load in processing them. Thus, the questions to reflect on concern whether it's possible and, if so, how to support 'embedded discourse representation,' a process that embeds comments directly into the display of the artifact under discussion. In informal and formal studies, students appear to prefer embedding their discussion directly into the artifact window (as comments) rather than switching between that window and the chat window (Wojahn 1998; Suthers, 1999). Because the discourse always takes place in the context of the artifact, *embedded communication tools* have the advantage of making it easier to refer to parts of the artifact and to recover the portion of the discussion that is concerned with a given part.

Some embedded communication tools, designed to establish and carry on a discussion in the context of the visual artifact include: (a) *Annotation tools* (sticky notes) that allow the embedding of comments directly into the display window of the artifact under discussion (Dimitracopoulou & Komis, 2004); (b) *Drawing*, the disclosing or indication of a representation or a part of a representation (e.g. diagram) under discussion; and (c) *Highlighting* parts of a diagram under discussion. In reality, this final option supports 'gestural deixis' (Suthers et al., 2003), enhancing the deistic value of the cursor by making its location more visible. If the user passes the cursor over an object, the object will be highlighted in a particular color and if the user deliberately selects an object with the cursor, this object is then highlighted in another color. In fact, all three of these design options are metaphors for the actions undertaken by pupils when working in the traditional paper-pencil mode.

Some disadvantages are that the record of discourse is fragmented across the artifact, making it more difficult to get a sense of the whole discussion or to notice relevant relationships between discussions about different parts of the artifact, and the possibility that the artifact becomes cluttered with comments. It would be beneficial, therefore, to be able to recover chronological versions of the discourse and perhaps to index the discourse in ways other than those done so by artifact components or chronology.

The trade-off between parallel and embedded communication tools could be resolved by conceiving of a system of *linked dialogue representations* tools, which would provide a logical link between tools that could then be viewed in virtually embedded ways if needed. It would also be useful to be able to switch between parallel and embedded representations (create a note in one representation and view it in another) (Suthers et al, 2003). This approach could resolve the conflict between the typically linear structures of parallel discourse tools and the contextual indexing of embedded discourse representations.

The Trade-off Related to the Coordination of Action and Dialogue

Related to the question of the coordination of action during synchronous collaboration, we consider that two interrelated trade-offs have emerged: (a) the existence or not of specific coordination protocols, (b) the specification or not of the 'rights' on collaborator contributions.

(a) Restricted collaboration protocols vs free ones: During collaborative learning, a common final product is expected from the participants, making a shared workspace and a shared point of reference necessary. In the case of synchronous collaboration, the question that arises is whether or not the production of the final product must be coordinated or better left free. This question is applied for action-driven systems as well as text-driven ones.

An implication of a restricted protocol (applied using, for instance, the metaphors of a 'key or pencil exchange,' or even 'traffic light') is that deadlocks can be created in cases where one partner cannot proceed with problem-solving alone and at the same time refuses to pass the key over to the other partner. The advantage, however, seems to be that the protocol maintains clear semantics of a participant's actions and roles in the shared workspace (Soller et al. 2002; Feidas et al, 2001).

Currently, there is also an interest in examining the possible need for communication protocols in the case of oral dialogue. Is the application of an oral dialogue coordination system needed or should there be a free one, where participants are invited to regulate their oral discussion by social agreement? In the 'Lyceum Project' (Bunkingham et al. 2001), using a videoconference system without imposing a control (i.e. anyone can speak anytime), adult participants 'learn' to take turns and maximise flexibility for different kinds of 'meetings.' In such a case, interactional fluidity is a useful and important skill for newcomers to learn. Another approach could require the use of metaphors such as conjuring up 'microphones' that would either be 'passed' among group members themselves or by a 'chairperson/group leader.'

It is to be noted that coordination protocols were eventually applied in all the early systems, making them easier to implement. However, where both approaches are technically possible, there's a need to re-examine the necessity of a coordination protocol (Dillenbourg, personal communication, May 2002), and specifically, to take into account the preferences of users themselves.

(b) Rights on partner contribution modification and the identification of ownership: In fact, the question of coordination protocols is also related to the concept of "*workspace awareness*" and the '*ownership*' of parts of the collaborative construct. What are the rights that each partner has on the contributions of the other partner? Some designers have left this free (e.g. in 'Modeler Tool,' Koch et al., 2001), without utilizing any locked mechanism, while others prefer to lock them to all other persons than the object's owner (e.g. 'Representation,' Komis, et al., 2002). In order to answer this question, an experiment was organised using two alternative collaboration protocols (Feidas, et al. 2002). Groups "A" had no ownership control, while groups "B" maintained ownership of introduced objects, so partners were not allowed to modify objects introduced by their peers. In the case of groups "B", every time a partner needed to modify an object of different ownership, a negotiation phase had to be initiated in order to convince the object's owner on the need for the proposed modification. By contrast, the groups without ownership control, displayed instances of disagreement during

collaboration. We could argue, therefore, that eventually students need *a clear indication of 'ownership'* (with direct or indirect indication of the names of the owners of each item) in order to regulate their activity and avoid this kind of conflict. Instead of locking mechanisms, however, we propose the addition of optimistic, concurrent control by supporting awareness, a process indicating exactly who currently uses which component. This could give the student more freedom and foster teamwork.

The Trade-off Between Metacognition Support for Self-Regulation and Teacher Support

This is a trade-off that actually arises simultaneously with an increasing research interest in the production of tools and functions for student and/or teacher support (Muhlenbrock & Hoppe, 1999; Jermann et al, 2001, 2002; Barros et al, 2002, Avouris et al, 2003; Martinez et al, 2003; Morch et al, 2003; Fessakis et al, 2004).

Let us first examine the actual possibilities, tendencies and new requirements for the self-regulation of student support. The skill of self-regulation is referred to as one of the meta-cognitive skills that allows a learner to concentrate on his/her own thinking process, successfully controlling it in order to independently achieve his/her goals (Brown, 1987). Systems that contribute in this direction are not those that reflect interactions ("mirroring systems," according to Jermann et al., 2001), but those that monitor the state of interaction by providing collaborators with literal information (Barros et al., 2002) or visualizations that can subsequently be used to self-diagnose and self-regulate interaction. Visualizations typically include a set of indicators that represent the state of interaction, possibly placed alongside a set of desired values and metrics for those indicators. Different kinds of appropriate visualizations have been produced, including graph-like visualizations, such as bar charts, pie charts, etc. that are used in problem-solving activities (Jermann et al, 2002, Fessakis et al, 2004), 'nested boxes' used in forum discussions, (Simoff, 1999) and even social networks used in cases of wide community exchanges (Martinez et al, 2003). The hypothesis is that the visualization structures of student discussion and actions, conducted through a suitable representation, can assist students in developing meta-cognitive mental activity and subsequently self-regulate their collaborative activity.

In general, examining current interaction analysis as related to literal or numerical information, or better, implemented visualization tools that are intended to function as meta-cognitive tools, we can distinguish that: (a) information may concern the whole group or each member of the group, (b) analysis may be based only on the actions of collaborators or their dialogues, (c) analysis may concern only the collaboration quality or the content of the activity, and (d) analysis may be based on either basic indicators (e.g. participation rates) or higher order indicators (e.g. related to collaboration modes or the quality of the solution).

It is to be considered that, for instance, in collaborative problem-solving, meta-cognition is not only related to the interaction itself but also to the strategic reasoning linked to the task. There is the assumption that regulation of the interaction and regulation of the task are closely related mechanisms and their co-occurrence facilitates coordination. Instead, however, the existing meta-cognitive tools for collaborative activities are based on statistical indicators of participation and collaborator actions or messages rather than on higher order qualitative indicators. These aspects are further discussed in Avouris et al. (2003) and Jermann et al. (2001).

The whole question of the design of appropriate meta-cognitive tools must be further investigated by the research community and in relation to: the category of students' activity (e.g. a game or a high cognitive demanding task), the collaboration mode, the age of pupils, and the kind of group (e.g. small, large group).

Up to the present, researchers have focused more on student self-regulation, while they have neglected teachers. Yet, students naturally seek the teacher's help when they realize that more information is needed to profitably continue an interaction. Therefore, we consider that most of the existing collaboration systems present limitations when used by young students in real school settings. Some of these limitations are attributed to the fact that the teacher, who is in charge of several students, fails to interpret the enormous number of complex interactions that can take place simultaneously. Two crucial questions are, "*How could we help teachers fulfill those responsibilities in computer-based collaborative situations?*" and "*How can teachers be supported with appropriate tools to help students*?"

There has not been enough research done on the significance of the teacher's role during network-based collaborative learning and the fact that teachers can derive useful knowledge from observing or participating with their students in CSCL environments (Lund & Baker, 1999). While some research has focused on the kinds of teacher interventions, there haven't been any looking at how we could support teachers to proceed to these interventions and what their needs are during the coaching of collaborative students.

In order to examine the needs of teachers during synchronous collaboration and determine corresponding requirements, experimentation was conducted (Petrou & Dimitracopoulou, 2003). The question was to examine teacher behavior during synchronous problem-solving with known and currently accepted learning activities (not innovative ones). Teachers applied two complementary scenarios for their interventions: (a) on-line supervision of a group collaborating in a synchronous mode, and (b) off-line analysis of the preceding intervention. Here, each teacher studied the students' interactions, then during the next session intervened in order to discuss some concepts or to propose new problems. The analysis of individual and panel interviews with teachers concluded that there is a need to design and develop better tools or partial functions, including (a) supervising tools and facilities, (b) elaborated and linked history of the whole interaction and (c) tools that produce an automated assessment of students' interactions. It appears that the most difficult requirement to accomplish would be the third one: *How to provide a rich variety of analysis output to assist teachers or facilitators?*

Actually, the underlying design and research work is in progress and is merely at a premature stage. We consider that the existing approaches (regarding the support of students' self-regulation and guidance from the system or support for the teacher in order to assist his/her students) are all valuable. However, it would be much more so if these approaches could be combined in a single learning environment allowing control or the self-regulation to be divided among the involved agents (collaborators, teacher, system).

The Trade-off related to the different kinds of collaborative learning environments

Up to the present, most designers and researchers have focused their work on one of the two dominant kinds of collaborative learning systems: (i) systems that promote collaborative problem-solving and work with a small number of collaborators, such as action or argument-oriented systems (e.g. COLER, C-CHENE), and (ii) systems that are directly addressed to a wide community, usually aiming at collective knowledge-building and understanding through text production (eg. CoVis, Knowledge Forum). The design of the first category of systems puts more stress on the tools for shared action, dialogue and meta-analysis, while the design of the second category focuses on the shared document repository, the structure and the multiple visualization of the material created from the community, the discussion forums, etc. The first category uses more synchronous communication tools, while the second one is mostly based on asynchronous tools.

Nowadays, the trade-off between these two general categories does not seem to be so relevant. On the one hand, researchers on the community-based systems, have recently recognized that it is worthwhile to incorporate some tools and functionalities for synchronous communication and collaboration (Lethinen, 2002), allowing students to organize their work, clarify ideas and enhance social awareness. On the other hand, systems for collaborative problem-solving, when used in a school environment, can enrich learning objectives when they support exchanges between students in a class. This includes the exchange of materials, ideas and difficulties, fostering an inquiry learning process. In this sense, we consider that every collaborative problem-solving system needs to be accompanied by a community support system and, therefore, incorporate tools and features used by the latter. Thus, repositories, group formation and off-line/social awareness functions are important features in any environment. Currently, this approach started to be adopted by some collaborative problem solving systems, such as Cool Modes and MODELLINGSPACE.

TRENDS IN NECESSARY TOOLS AND FUNCTIONS

Synthesizing the aspects presented in the previous analysis on the design trade-offs related to tools and functions, and remaining faithful to our central aim of designing advanced systems that support collaborative learning in real school contexts in an essential way, we propose a design framework consisting of the following four fundamental considerations:

(A) *A vision of all agents and cognitive systems involved in collaborative learning settings:* The agents that seem to be considered in some collaborative environments are often seen from a one-dimensional point of view. In reality, during collaboration the main actor is neither only the *individual-member* of a collaborative team nor only the *team as a whole*. Both of these 'aspects' are important, but equally so is the case of *the whole community* formed of individuals and groups collaborating in various modes. On the other hand, a learning process (at least in the frame of primary/secondary education), involves both learners and *teachers.* The learner-centered design approach, being dominant during the last decade, has positively influenced designers, but has also presented the following drawback: by focusing in principle on the individual learner, it takes the other agents involved out of the cycle (Dimitracopoulou, 2001). These agents may form *one or more cognitive systems*, in the sense of distributed cognition theory (Salomon, 1995). Consequently, all agents involved in the process must be considered important and may need to have specific tools at their disposal. Thus, we need to consider each actor: (a) the individual, (b) each specific team, (c) the whole learners' community that is formed and (d) the teacher(s).

(B) *A complete view of the necessary tools and functions supporting collaborative learning:* In the ideal case, each agent and each cognitive system needs some basic tools to fulfill five general functions that allow and support collaboration for achieving learning progress. These five functions are: (a) *Action and discussion function*s, leading to action or text production tools, as well as dialogue tools; (b) *Course Management,* leading to tools for the management of the learning material (e.g. repositories, group formation tools, etc.); (c) *Workspace awareness' functions,* leading to functions related to immediate workspace awareness as well as to a larger social awareness of all the events that happen in the wider learning community; (d) *Analysis and meta-analysis tools* supporting self-regulation and metacognition for students, including teachers' tools for supervising and analyzing collaborative interactions either in an on-line or off-line mode; (e) *Help and Advising functions* leading to simple help systems or more advanced advising systems for students and teachers.

(C) *A vision of a mixed category of collaborative learning systems:* Analyzing what kinds of tools are developed per category of systems, it is determined that there are two dominant systems' categories: (a) systems that focus on the collaboration between a small group of learners and (b) systems that are addressed from the beginning to a wide community of learners. These two categories are actually sufficiently developed, given the specific focus of each kind of environment (problem-solving or exchanging ideas). Therefore, it is currently possible to develop systems that draw from both of these categories, presenting mixed features.

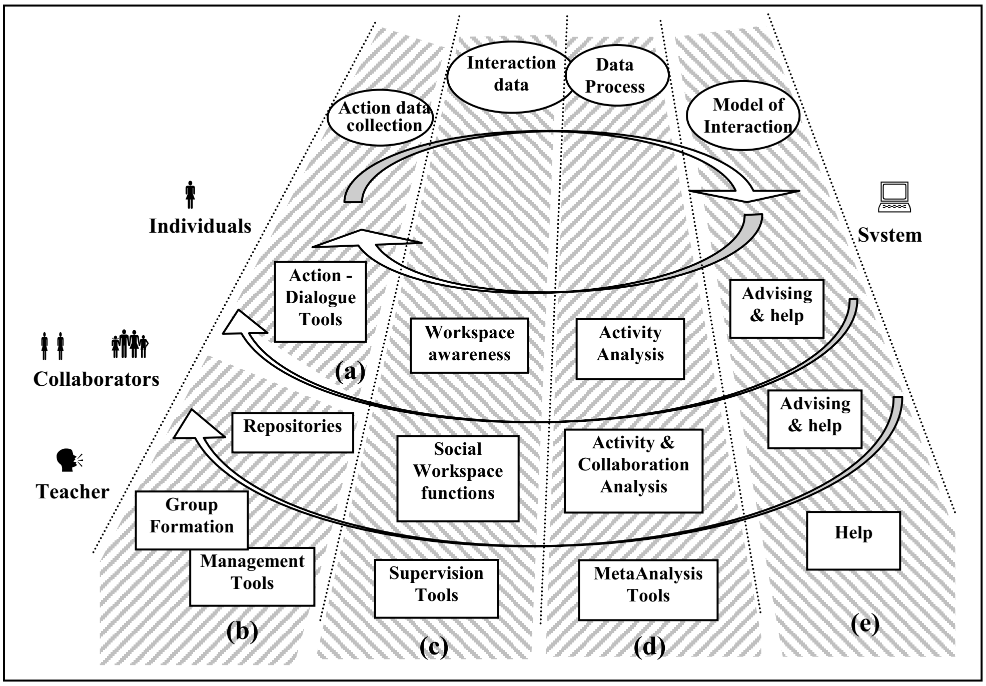

Figure 1. System processes during collaborative activity that offer tools and functions to the involved human agents

(D) *A vision of the control of the collaborative process as distributed to all the agents*: In our point of view, it would be fruitful to work on the direction of *expanding the management of the collaboration* to all the agents: 'individual,' 'collaborators,' 'teacher' and 'system.' This expanded collaboration management would be possible, according to an approach based on a number of general *principles,* allowing for determining the need for an agent (human or artificial) to intervene as well as dictating the specific sub-role that this agent should undertake. The current approach is often based on a well-defined desired state, according to which the system advises the collaborators. This approach does not seem to be the most appropriate, given that it is valid only in very specific cases of activities, problems, conditions and student profiles. Generally, knowledge construction activities are open and flexible, while such a model is quite restrictive.

According to these fundamental considerations, we could examine now, how a generic collaborative learning system functions, how it processes the whole interaction, what functions it assures and to whom it is addressed (see Figure 1). The individual user has available the tools for action and dialogue in order to function in a private workspace or interact and collaborate through a shared workspace. In order to manage production, users have also access to specific tools (e.g. repositories). The collaborative learning system internally collects the data of each user's actions as well as that of the interactions among all participants and then processes this data, eventually constructing a model of actions and interactions. This system assures the continuation of the five main functions that are necessary to support collaboration. However, according to the first consideration, we can argue that there exist at least three simultaneous processes that correspond to the three main agent profiles: individual, collaborators and teacher. Thus, in order to fulfil individual needs the system may advise, offer information (visually or verbally) based on activity analysis or support other basic functions such as the assurance of workspace awareness. In order to support the group of collaborators, it may produce advice, present information derived from high-level indicators through a meta-analysis of collaborative activity or raise social awareness. Similarly, help functions addressed to teachers may be assured and supervision tools as well as individual, collaborative or even comparative information may be presented, based on an analysis of all interactions.

CONCLUSIONS: RESEARCH AGENDA TOWARDS MORE APPROPRIATE SYSTEMS FOR REAL SCHOOL SETTINGS

There are many ways to promote collaborative learning: gathered around the computer, through new technological gadgets, through a balanced combination of various existing tools on the web, etc. In this paper, we have based our analysis and discussion on collaborative systems that have been designed for learning purposes and a wide range of learning activities. In all these systems, collaborative learning is viewed as a pedagogical method that can stimulate students to discuss information and problems from different perspectives, to elaborate and refine these in order to re-construct and co-construct (new) knowledge or to solve problems. In such situations, externalization, articulation, argumentation and negotiation of multiple perspectives are considered the main mechanisms that can promote collaborative learning (Dillenbourg et al., 1999; Baker et al., 2001; Veerman, 2000). These systems have allowed for new learning settings and have managed to develop new cognitive and metacognitive tools to support learning and collaboration.

The evolution of research on the design and development of collaborative learning systems have had an effect on the emergence of some significant trade-offs related to the means of dialogue, the coordination of action and dialogue, the self-regulation/metacognition support of students and the analysis and meta-analysis tools for teachers as well as recognition of the differences between ‘problem-solving oriented systems’ and ‘wide community systems’.

In conclusion, we argue that the research design agenda of the immediate future needs to be focused on the following axes:

i) Accentuation of the effort to produce rich systems: The unification of designers’ efforts working on different collaborative system categories and under an open vision of all the possible ‘human cognitive systems’ formed during various collaborative modes, could produce richer systems, which are more appropriate for various collaborative settings, conditions and contexts.

ii) Elaboration of powerful analysis methods of collaborative interactions: Researchers are in the process of developing methods that have the potential to derive rich analysis and meta-analysis results, taking into account a number of aspects: (a) the whole content of the activity with both actions and dialogues, (b) the collaboration modes and quality, (c) the context of the collaboration and (d) each cognitive system’s (individual, group, wide community) needs.

ii.a) Development of visualized meta-cognitive tools addressed to students: For this purpose, research has to focus on the investigation of appropriate visualization modes that could produce metacognitive tools that are able to support young students in both learning and the collaboration process.

ii.b) *Development of visualized tools addressed to teachers:* It has just recently been acknowledged that one actual new research direction should be related to how we could take profit from the traces/transcriptions of students in order to facilitate the teacher’s analysis task allowing him/her to apply diagnosis and, thereafter, scaffolding. This is needed to provide appropriate analysis and meta-analysis results with appropriate visualizations that could support teachers when needed to intervene during or after the interaction.

iii) *Production of flexible and negotiable environments that respect the sustainability and reusability of the elaborated work:* Lessons learned from technology-based learning environments in schools suggest that we need to consider the school as a community of practice, creating systems that allow people to perform as well as they are able to and then to amplify, transform, and extend their work to new or additional outcomes. Brown (2000) argues that information-driven technologies and their implementation need to be grounded in the social life of the school. Given that most of the schools do not have a long history in the exploitation of these environments, it is important to provide *flexible architectures and customisable tools,* studying how they work in schools, particularly in different cultural and educational contexts. Research often concludes after a short period of implementation time, without working with the possibility that students and teachers can adapt and negotiate the use of tools for their perceived needs (Baker et al. 2001; Dimitracopoulou, 2001). Additionally, it is crucial to assure the *sustainability and reusability* of the work done in a software development perspective, designing interoperable systems that are open and easily extendible (Hoppe & Gabner, 2002).

iv) *Collaborative learning activities and tasks regarding various collaboration modes:* We need to always keep in mind that it is not only the features of the technology used but especially the way technological artifacts support collaboration in real settings (Lehtinen, et al 1999). A crucial parallel research agenda concerns the design of appropriate collaborative learning activities and modes for different learning purposes and student age levels (Dimitracopoulou & Ioannidou, 2003). The effort to elaborate on the semantics of collaborative scripts is promising and assists in raising the awareness of a rich range of choices (Dillenbourg, 2002).

(v) Exploration of the new possibilities offered by ubiquitous computing and wireless devices: As technology evolves, new design and research possibilities are revealed. Specifically, the ubiquity of computing and handheld computers offers new physical media, different from those of traditional computer-supported collaborative learning applications (Roschelle & Pea, 2002). Subsequently, what is needed is an investigation of

many of the new functions and interfaces of these promising devices, assuring their corresponding usability. As well, research must look at how such devices open up a world of new powerful learning activities.

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Supporting CSCL with Automatic Corpus Analysis Technology

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Abstract. Process analyses are becoming more and more standard in research on computer-supported collaborative learning. This paper presents the rational as well as results of an evaluation of a tool called TagHelper, designed for streamlining the process of multi-dimensional analysis of the collaborative learning process. In comparison with a hand-coded corpus coded with a 7 dimensional coding scheme, TagHelper is able to achieve an acceptable level of agreement (Cohen's Kappa of .7 or more) along 6 out of 7 of the dimensions when we commit only to the portion of the corpus where the predictor has the highest certainty. In 5 of those cases, the percentage of the corpus where the predictor is confident enough to commit a code is at least 88% of the corpus. Consequences for theory-building with respect to automatic corpus analysis are formulated. Potential applications as a support tool for process analyses, as real-time support for facilitators of on-line discussions, and for the development of more adaptive instructional support for computer-supported collaboration are discussed.

Keywords: Corpus analysis, automatic text processing techniques, argumentation

PROBLEM BACKGROUND

Increasingly, research in CSCL addresses quantitative process analysis through multi-dimensional coding schemes (e.g., Fischer, Bruhn, Gräsel, & Mandl, 2002; Lally & De Laat, 2002). The process of collaboration is seen as a mediator between the computer-supported instructional settings and cognitive processes. Often only detailed process analyses reveal plausible interpretations of the effects of CSCL environments (Weinberger, 2003). Conducting detailed process analyses involves applying categorical coding schemes along multiple dimensions, each of which indicate something different about the text segment's function within the collaborative discourse. For example, Lally and De Laat (2002) code for activities along six dimensions including cognitive, meta-cognitive, affective, design, discourse maintenance, and direct instruction. Multi-dimensional coding schemes like these encode much more information than frameworks in which each text segment is coded with a single category. However, while single dimensional analyses can be expedited by requiring participants to select contribution openers that are indicative of contribution function, this is not practical with multi-dimensional coding. Furthermore, applying multi-dimensional categorical coding schemes by hand is extremely time intensive for three reasons. First, developing the coding schemes themselves in such a way that human coders can apply them reliably is a lengthy process requiring much iteration. Second, sophisticated coding schemes may require a high skill level and intensive training before coders can apply a well-designed coding scheme with high reliability. Thus, training time for learning a new coding scheme is another source of time expense involved in this type of research. Finally, applying coding schemes as part of the analysis process itself is a tedious and time consuming process. Surprisingly, although structured editors often support this work, other times it is done by pen and paper. We therefore conducted a study to find out the degree to which automatic classification technology can be successfully used to automate the challenging task of multi-dimensional quantitative process analysis.

In this paper we present results of an evaluation study of the TagHelper technology for supporting and streamlining the process of multi-dimensional analysis of the collaborative learning process. We begin by contextualizing our technological explorations within a high profile CSCL environment. We then review related work and explain how our work is unique and complementary to previous automatic analysis work within the CSCL community. We then describe our exploration process and the details of our evaluation. We conclude with discussion and current directions.

MOTIVATION

The main question addressed in this paper is the extent to which automatic classification technology can be used to automate the task of multi-dimensional quantitative process analysis. Addressing this question, we first present a promising approach to this challenging task - TagHelper technology. Then we report on major results of an evaluation study of TagHelper in the context of a high profile CSCL project. In this project, a multi-dimensional coding scheme is applied to massive amounts of discourse data in order to examine the process of collaboration under different instructional conditions.

Within the context of this project, a series of experimental studies were conducted that aimed to address the question of how computer-supported collaboration scripts could foster argumentative knowledge construction in online discussions. Argumentative knowledge construction is based on the perspective of cognitive elaboration, the idea that learners acquire knowledge through argumentation with one or more learning partners (Baker, 2003; Dillenbourg, 2004). Computer-supported collaboration scripts apply on specific dimensions of argumentative knowledge construction, e.g., a script for argument construction could support learners to ground and warrant their claims (Kollar, Fischer, & Hesse, 2003; Stegmann, Weinberger, Fischer, & Mandl, 2004) or a social collaboration script can support conflict orientation (Weinberger, 2003). These and other computer-supported collaboration scripts were varied experimentally (see Stegmann et al., 2004; Weinberger, 2003; Weinberger, Fischer, & Mandl, submitted for more detailed process analyses). These studies were conducted in three waves. The first wave took place in the winter of 2000/2001, the second in the winter of 2002/2003, and the third in the winter of 2003/2004. The complete process analysis comprises about 200 discussions of about 600 participants with altogether more than 17,000 coded text segments. Trained coders categorized each segment using a multi-dimensional coding scheme (see below).

Three groups of about six coders, one group for each wave, were trained to apply the coding scheme to the collected corpus. One and the same trainer advised the analysts during all of the three waves. Each coder received a booklet with a detailed description of the coding scheme including all coding rules and examples for each category to ensure coding reliability. The training consisted of a combination of group meetings, dyadic practice, and individual practice. At regular intervals the reliability of the coding was computed by means of Cohen's Kappa. Discrepancies were then discussed and resolved. *Between the training and the coding itself, one quarter of the total duration of the research project was used for the coding of collaborative processes.* In particular, the training for each group of coders requires about several weeks, or about 500 working hours completely dedicated to the training process. The coding itself took about one month per wave, or about 1200 working hours.

Obviously a fully-automatic or even semi-automatic system, which could support coding of natural language corpus data, e.g., from computer-supported text-based communication, would facilitate and potentially improve quantitative process analyses in multiple ways. First of all, the number of working hours could be dramatically reduced for both training and coding. The role of the analysts could be reduced to simply checking the automatic coding and making corrections if necessary. Thus, the level of expertise of the coders could potentially be reduced, which would further reduce the cost. The coding itself would be faster. As learning processes could be analyzed promptly, even on the fly, facilitators could quickly identify specific deficits of collaborative learners as they are interacting and offer specific instructional support at key points.

OVERVIEW OF EXISTING TECHNOLOGY

Richards (1999), Soller & Lesgold (2000) and Goodman et al. (to appear) present work on automatically modeling the process of collaborative learning by detecting sequences of speech acts that indicate either success or failure in the collaborative process. The automatic analysis presented in this previous CSCL work builds upon an already completed categorical analysis of the text. These analyses can be thought of as meta-analyses with respect to the type of analysis we speak of. In contrast, the analysis that we present in this paper is based on the raw text contributed by the participants in the collaborative learning scenarios. What is different about our approach is that we start with the raw text and detect features within the text itself that are diagnostic of different local aspects of the collaboration. Thus, rather than presenting a competing approach, we present an approach that is complementary to that presented in prior work.

Currently there is a wide range of corpus analysis tools used to support corpus analysis work either at a very low level (e.g., word frequency statistics, collocational analyses, etc.) or at a high level (e.g., exploratory sequential data analysis once a corpus has been coded with a categorical coding scheme), but no tools to support the time consuming task of doing the categorical behavioral coding or content analysis, although much applicable technology developed in the language technologies community is already in existence. Content analysis includes both categorical analyses as well as more detailed, bottom-up analyses where spontaneous, informal observations about verbal behavior are recorded. In this paper we address the problem of streamlining the categorical type of protocol analysis.

	Components	Existing Technology	Existing Tools
Low Level Analysis	Word frequencies, word counting, morphsyntactic processing, collocation analysis	Tokenizers, Morphologicial analyzers, some shallow syntactic parsing	CLAN, SHAPA, TraSA, MultiTool, etc.
Medium Level Analysis	Various sentence level and segment level labeling tasks	LSA, CarmelTC, various dialogue act tagging approaches	
High Level Analysis	Exploratory sequential data analysis, Educational Data Mining	Statistics, data base queries	CLAN, SHAPA, ELAG, etc.

Figure 1. Abbreviated overview of some existing corpus analysis tools and technology

Currently, the only existing tools to support categorical content analysis are structured editors similar to Nb (Flammia & Zue, 1995) and MATE (McKelvie et al., 2000) or a wide variety of XML editors. We are exploring the application of state-of-the-art dialogue act tagging and text classification technology to enable fully and semi-automatic coding.

Applying Language Technology to a Previously Unexplored Application

Applying a categorical coding scheme can be thought of as a text classification problem where a computer decides which code to assign to a text based on a model that it has built based on regularities found from examining "training examples" that were coded by hand and provided to it. A number of such statistical classification and machine learning techniques have been applied to text categorization, including regression models (Yang & Pedersen, 1997), nearest neighbor classifiers (Yang & Pedersen, 1997), decision trees (Lewis & Ringuette), Bayesian classifiers (Dumais et al., 1998), Support Vector Machines (Joachims, 1998), rule learning algorithms (Cohen & Singer, 1996), relevance feedback (Rocchio, 1971), voted classification (Weiss et al., 1999), and neural networks (Wiener et al., 1993). While these approaches are different in many technical respects that are beyond the scope of this paper to describe, they are all used in the same way. A wide range of such machine learning algorithms are available in the Minorthird text-learning toolkit (Cohen et al, 2004), which we use as a resource for the work reported here. Minorthird is a software package that includes a wide range of configurable machine learning algorithms that can be used for text classification experimentation.

Within the computational linguistics community, a very common type of categorical coding scheme applied to text is that of speech acts or dialogue acts (Chu-Caroll, 1998; Reithinger & Klessen, 1997). Classifying spoken utterances into dialogue acts or speech acts has been a common way of characterizing utterance function since the 1960s. We argue that the same basic technology has the potential to achieve a much broader impact by becoming more accessible outside the computational linguistics community as well as using a broader range of coding schemes. One example of a community where this technology could have a major impact is the CSCL research community where large quantities of natural language data are being collected and analyzed painstakingly by hand.

Unfortunately, existing text classification technology is largely inaccessible to CSCL researchers who need and want semi-automatic tagging support because they do not have the background to apply it effectively to their analysis tasks. They are largely unaware of the wide range of alternative text classification techniques that are available, and furthermore, they do not possess the technical skills required to predict which available approaches are likely to be most appropriate for their task or to tune an appropriate technique once selected.

Bridging the Gap Between Language Technology and CSCL Research

The goal of our current work is to bridge the gap found in existing corpus analysis tools used by CSCL researchers for analyzing corpus data. In this paper we focus on the highly accurate text classification technology that enables some categorical corpus analysis work to be done totally automatically. In other work we have developed and tested an easy-to-use adaptive coding interface (Rosé et al., submitted). The easy-to-use TagHelper interface displays its automatic predictions about the analysis of each span of text to the analyst in the form of an adaptive menu-based interface. The system's predictions are visible to the analyst as he scans the page and modifies only the codes that he disagrees with by making an alternative selection.

Rosé et al. (submitted) have evaluated TagHelper's novel adaptive interface for facilitating content analysis of corpus data in comparison with an otherwise identical non-adaptive interface in terms of speed, validity, and reliability of coding. Since deciding to disagree with a predicted code and then choosing a new code takes longer than selecting a code from scratch, the advantage in coding speed for automatic predictions depends upon the accuracy with which predictions can be made. In order to break even with speed, a prediction accuracy of at least 50% is required. 50% prediction accuracy leads to an increase in reliability and validity of coding. In an evaluation with novice analysts in (Rosé et al., submitted), the top 30% of novice coders working with the automatic predictions achieved an average pairwise Kappa agreement measure of .71 in comparison with .54 in the unsupported coding condition ($P < .05$). Novice agreement with a gold standard was marginally higher ($P < .1$) across the whole population of coders. A gold standard corpus is a corpus that has been coded with a coding scheme, and the codes have been verified to be reliable. Thus, using automatic coding support, acceptable reliability and validity of coding can be achieved with novice coders using very little training. TagHelper can be quickly adapted for a new coding scheme and domain by providing only a small corpus of example texts encoded in XML and a simple specification of the structure of the coding scheme.

METHOD

In this paper, we examine the feasibility of TagHelper for supporting fully automatic analyses of the processes of argumentative collaborative knowledge construction. In this work, a human was required to optimize the selection and tuning of an appropriate machine learning algorithm. However, once a model was trained on the data using the selected technique, TagHelper was used to code data in a fully-automatic way.

Coding scheme for argumentative knowledge construction

In this section we describe a coding scheme that was applied in a project with more than 600 students of Educational Science at the Ludwig-Maximillians university of Munich, who participated in groups of three in multiple studies. Students in all experimental conditions had to work together in applying theoretical concepts to three case problems and jointly prepare an analysis for each case by communicating via web-based discussion boards. They were asked to discuss the three cases against the background of attribution theory (Weiner, 1985) and to jointly compose at least one final analysis for each case, i.e. they usually drafted initial analyses, discussed them, and wrote a final analysis. The cases portrayed typical attribution problems of university students, e.g., a student interpreting his failure on an important test. All groups collaborated in three discussion boards – one for each case. The discussion boards provided a main page with an overview of all message headers, which were graphically represented in a discussion thread structure. Learners could read the full text of all messages, reply to the messages, or compose and post new messages. In the replies, the original messages were quoted with ">" as in standard newsreaders and e-mail programs.

The purpose of our analysis was to model the process of argumentative knowledge construction. Argumentative knowledge construction must be evaluated on multiple process dimensions (Weinberger & Fischer, in press). These dimensions are derived from different theoretical approaches and focus on different concepts of argumentative knowledge construction. The main concepts are (1) epistemic activity, formal quality of argumentation, which includes (2) microlevel and (3) macrolevel, and (4) social modes of interaction (with a sub-dimension for (5) reaction). In accordance with the theoretical approach, the number of categories differs between dimensions from 2 (e.g., reaction) to 35 (e.g., epistemic). For experimental reasons, there is also a (6) treatment check dimension and a (7) quoted dimension.

On the *(1) epistemic dimension* (see table 1), argumentative knowledge construction processes are to be analyzed with respect to the questions of how learners work on the learning task, e.g., what content they are referring to or applying. One important distinction on the epistemic process dimension is to what extent learners work on the task or digress off task (Cohen, 1994). In order to solve a problem, learners may need to construct a problem space, construct a conceptual space, and construct relations between the conceptual and problem spaces. With the *construction of the problem space*, learners are to acquire an understanding of the problem they are supposed to work on. Therefore, learners select and relate individual components of the problem case information. The *construction of the conceptual space* serves to communicate an understanding of a theory. Learners connect individual theoretical concepts or distinguish them from another. The *construction of relations between conceptual and problem space* indicates to what extent learners are able to apply theoretical concepts adequately. In particular, learners may apply theoretical concepts that are to be learned, apply concepts stemming from prior knowledge or also apply wrong concepts.

On the formal dimension of argumentation, the processes of argumentative knowledge construction can be examined on both a micro- and a macrolevel of representation that indicate how learners construct single arguments and how learners connect arguments into sequences. In contrast to the epistemic dimension, the formal dimension of argumentative knowledge construction is not as concerned with what learners are contributing, but how they construct arguments and argumentation sequences in order to make their point.

Table 1: Categories of epistemic dimension of argumentative knowledge construction

Category	Description
Construction of problem space	Retelling or rephrasing of the problem that the learners work on. Learners relate case information to case information. Aims to foster understanding of particularities of the problem.
Construction of conceptual space	Retelling or rephrasing the theory learners are supposed to apply. Learners relate theoretical concepts and explain theoretical principles to foster understanding of a theory.
Construction of adequate relations between conceptual and problem space	Applying the relevant theoretical concepts adequately to solve a problem. Learners relate theoretical concepts to case information. A number of concept-case-relations may need to be constructed to adequately solve a complex problem (ca. 30 concept-case-relations for each case problem of the Munich study)
Construction of inadequate relations between conceptual and problem space	Applying theoretical concepts inadequately to the case problem. Learners may select the wrong concepts or may not apply the concepts according to the principles of the given theory.
Construction of relations between prior knowledge and problem space	Applying concepts that stem from prior knowledge rather than the new theoretical concepts that are to be learned.
Non-epistemic activities	Digressing off-topic.

On the (2) *microlevel*, an individual argument consists of a claim, which can be grounded with a warrant and/or specified by a qualifier (Toulmin, 1958; Toulmin, Rieke, & Janik, 1984). The warrant contains a justification for the claim based on grounds. The qualifier limits the validity of the statement and can be sometimes represented implicitly in the structure of an argument, e.g., indicated by "perhaps". We regard the frequent use of warrants and qualifiers in an argument as an indicator for high argumentative skill (see table 2).

On the (3) *macrolevel*, argumentation sequences can be examined with respect to how learners connect single arguments and create an argumentation pattern together (Leitão, 2000). The analysis typically focuses on the rhetorical function of individual expressions in a sequence of contributions. Central concepts are argument, counterargument and reply/integration (see table 3).

Table 2: Categories of microlevel of formal dimension of argumentative knowledge construction

Category	Explanation
Simple claim	Expressing a claim without qualifying the claim or providing grounds that warrant the claim.
Qualified claim	Expressing a claim without giving grounds, but limiting the validity of the claim (with qualifier).
Grounded claim	Explaining a claim without limiting its validity, but providing grounds that warrant the claim.
Grounded and qualified claim	Expressing a claim and grounds that warrant the claim as well as limiting the validity of the claim.

Table 3: Categories of macrolevel of formal dimension of argumentative knowledge construction

Category	Description
Argument	Statement put forward in favor of a specific proposition.
Counterargument	An argument opposing a preceding argument, favoring an opposite proposition.
Integration (reply)	Statement that aims to balance a preceding argument and counterargument.
Question (non argumentative)	Seeking information.
Planning (non argumentative)	Coordinating technical moves within the CSCL environment..
Evaluation (non argumentative)	Assessing the value of arguments or the group work.

The *(4) social modes dimension* (see table 4) indicates to what degree or in what ways learners refer to the contributions of their learning partners. On this dimension, a number of social modes of co-construction and their relations to individual knowledge construction have been identified (Fischer et al., 2002). Learners may explicate their knowledge, e.g., by contributing a new analysis of a problem case. *Externalizations* are discourse moves that neither refer to preceding contributions of peers nor aim to elicit information from the learning partners. Learners may use the learning partner as resource and seek information (*elicitation*) in discourse from the learning partners in order to solve a problem case. Learners need to build at least a minimum consensus regarding the learning task in a process of negotiation in order to improve collaboration (Clark & Brennan, 1991). There are different styles of reaching consensus, however. *Quick consensus building* means that learners accept the contributions of their learning partners not in terms of taking over his or her perspective, but in order to be able to continue the discourse (Clark & Brennan, 1991). Recent approaches towards collaborative learning stress that collaborative learners may eventually establish and maintain shared conceptions of a subject matter (*integration-oriented consensus building*). Learners approximate and integrate each other's perspective, synthesize their ideas, and jointly try to make sense of a task (Nastasi & Clements, 1992). *Conflict-oriented consensus building* has been considered an important component in the socio-cognitive perspective upon collaborative learning (Doise & Mugny, 1984; Teasley, 1997). By facing a critique, learners may be pushed to test multiple perspectives or find more and better arguments for their positions (Chan, Burtis, & Bereiter, 1997).

In addition, any segment following an elicitation from another learning partner was coded on an explicit dichotomous *(5) sub-dimension of reaction* (no reaction vs. reaction). If a learner responded to an elicitation, e.g., by answering to a question, this response has been coded as reaction

Table 4: Categories of social modes dimension of argumentative knowledge construction (SOC)

Category	**Description**
Externalisation	Articulating thoughts to the group.
Elicitation	Questioning the learning partner or provoking a reaction from the learning partner.
Quick consensus building	Accepting the contributions of the learning partners in order to move on with the task.
Integration-oriented consensus building	Taking over, integrating and applying the perspectives of the learning partners.
Conflict-oriented consensus building	Disagreeing, modifying or replacing the perspectives of the learning partners.

The *(6) treatment check dimension* indicates how learners interact with the instructional design. The computer-supported collaboration script approach is often implemented with the help of prompts. These prompts support collaboration of learners and become part of the corpus data. This dimension considers how learners make use of prompts. Learners could *use the prompts in the intended manner*, e.g., write a counterargument when they are asked to write a counterargument. But learners could also *ignore the prompt*, i.e., write nothing in response to the prompt. If learners are prompted to write a counterargument but wrote an argument, it would be an *unintended use of prompt*. Obviously, this dimension could only be applied if prompts are part of the instruction. Prompts within the corpus data will be only analyzed on this single dimension.

Table 5: Categories of treatment check dimension of argumentative knowledge construction

Category	**Description**
Intended use of prompt	Reacting to this prompt like intended.
Ignoring prompt	Ignoring prompt. The action isn't connected with the prompt.
Unintended use of prompt	Using prompt, but not like intended.

The dichotomous *(7) quoted dimension* is a primary technical dimension (not quoted vs. quoted). As already mentioned before, in the replies, the original messages were quoted with ">" as in standard newsreaders and e-mail programs. Quoted text within the corpus data then will be only analyzed on this single dimension.

Experimental Process

We used the Minorthird text-learning toolkit (Cohen et al, 2004), which contains a large collection of configurable machine learning algorithms that can be applied to text classification tasks, as a framework in which to conduct our research. Because Minorthird includes a wide range of text classification algorithms that all operate over text coded in the same format, it is a convenient test environment for experimentation. We used as a gold-standard corpus as set of 1255 separate text segments coded with the multi-dimensional coding scheme described in the previous section. As described above, the coding scheme is composed of 7 dimensions, named epistemic, microlevel of argumentation, macrolevel of argumentation, social modes, reaction, treatment check, and quoted respectively. Each of these dimensions has a set of 2 or more categories associated with it. For example, macrolevel of argumentation has 7 (six theoretical and one "rest" category) such categories, whereas microlevel of argumentation has 5 (four theoretical and one "rest" category), and epistemic has 35 (thirty-four theoretical and one "rest" category). The "rest" categories comprise prompts and quoted text. Every text segment in the gold standard corpus is labeled with a category for each of the 7 dimensions. Our experimentation followed a typical pattern for corpus based research, which we describe in this section. In other words, we form hypotheses about what might work based on our understanding of the coding scheme and our experience with the machine learning algorithms. We then run experiments with those algorithms and use the results to deepen our understanding of the representation and the interaction between the machine learning techniques and the data. We then revise our hypotheses and run additional experiments. We experimented with a range of techniques in a semi-directed manner. It is this semi-directed experimentation process that we are working towards automating in our continued research. We believe that if we could automate this process, we will have found the final piece of the puzzle that is required to make this technology fully accessible to CSCL researchers so that it could be applied to new problems without the aid of an experienced computational linguist.

We began our experimentation by testing a non-binary classifier called K-Nearest Neighbors to assign a category to each text for each of the seven dimensions. The difference between a binary classifier and a non-binary classifier is that binary classifiers can only distinguish between two categories (i.e., positive examples versus negative examples), a non-binary classifier can in theory make any number of distinctions (e.g., the 35 types of epistemological categories). Since the majority of the 7 dimensions that are part of our coding scheme contain more than two distinctions, a non-binary classifier was the most straightforward approach to use as a baseline. We tested this approach using what is called a cross-validation evaluation methodology. What this means is that we divided our gold-standard corpus into 10 equal subsets of coded spans of text. For each of these 10 subsets of data, we trained a model from the other nine subsets and tested on the selected subset so that we were always testing on a different set of data than what we trained on. Each of these rounds of training and testing are referred to as an iteration. So there are 10 iterations of training and testing for a 10-fold cross-validation evaluation such as this. This process is important for obtaining an accurate measure of how well a trained model will perform on additional data since it keeps a separation between data used for training the model and data used for testing the model. Once we had a measure of performance over each of the 10 subsets of data, we averaged those in order to obtain an estimate for the whole set. Cross-validation evaluations are standard practice in machine learning research. We went through this process separately for each of the 7 dimensions. The results are presented in Table 5. The non-binary classifier only achieved an acceptable level of agreement with the gold standard in the case of reaction, achieving a Kappa of .81.

Table 5: Performance of Non-binary classifier over data

Name of Dimension	Number of Categories	Kappa
epistemic	35	.51
microlevel of argumentation	4	.54
macrolevel of argumentation	7	.54
Social modes	21	.35
reaction	3	.81
Treatment check	4	0
Quoted	2	.63

To assess the learnability of each of the categories along the 7 dimensions, we then began to experiment with binary classifiers. There is a much wider range of non-binary classifiers to choose from. For each category along each dimension we computed a Kappa value for a wide range of binary classifiers, each of which was given the task if distinguishing example texts that are assigned the corresponding category along its associated dimension and those that are not. We noticed that some categories were much easier to predict than others. Normally, it was the categories for which there were more than 25 examples in the corpus. Thus, we hypothesized that an approach where we cascaded the binary classifiers so that we first applied the most accurate classifiers and then the less accurate classifiers only if the accurate ones did not predict a positive match would be more accurate.

Again we adopted a cross-validation methodology. This time it was necessary to select on each iteration of the 10-fold cross-validation evaluation, not only a testing set, but also a validation set on which to determine the rank ordering of the individual binary classifiers. This is so that the set used for rank ordering the binary classifiers is not either the same set that they were trained over, nor the same set they will be tested over. This ensures both optimal training and most accurate testing. Thus, on each iteration, we trained a separate binary classifier for each category associated with each dimension over 8 subsets of data. We then tested the accuracy of these classifiers on the validation set. For each dimension, we rank ordered the binary classifiers according to their accuracy over the validation set. We then applied them in rank order over the test set, selecting as an assigned code the first binary classifier that indicated a positive match for an example text. We computed the accuracy of the cascaded classifier over each of the 10 test sets using this approach and then averaged the results as in the first experiment with non-binary classifiers. The assumption here is that if one classifier gives a higher Kappa value over the validation set, then it will most likely be more reliable in terms of predicting correct labels over the testing set, hence it is more probable that its prediction is correct instead of the classifier with a lower Kappa. The best results we obtained were with the Voted Perceptron Learning algorithm, which gives better results with our data in general than the other classification techniques such as DecisionTrees, NaiveBayes approach, SVM Learning, etc. In the next section we present our current best results.

OUTCOMES

Since the results for the reaction dimension were already acceptable with non-binary classification, we restricted our experimentation to the remaining 6 dimensions. In all cases we achieved a significant increase over the non-binary classification result except in the case of the epistemic dimension. We first present the Kappa we achieve over the whole corpus using the cascaded approach. We then present the Kappa we achieve if we use a more conservative approach, only assigning a category to the portion of the corpus where our performance over the validation set was highest. The task was accomplished by eliminating the least accurate binary classifiers from the cascaded model one by one until an acceptable Kappa was achieved. In that column we present the best Kappa we were able to achieve and the percentage of the corpus it was computed over. For example, for the macrolevel of argumentation we are able to achieve a Kappa of .83 over 92% of the corpus, leaving 8% of the corpus uncoded. In the case where this conservative classifier is used, a human coder only needs to code 8% of the corpus by hand since the accuracy over the automatically coded portion of the corpus is acceptable.

Table 7: The table compares the accuracy computed in terms of Cohen's Kappa between the gold standard codes and 3 approaches to automatic classification

Name of Dimension	Kappa for Non-binary Classification	Kappa for Cascaded Binary Classification Over Whole Set	Kappa for Cascaded Binary Classification Over Partial Set
Epistemic	.51	.49	.52 (43% of corpus)
Microlevel of argumentation	.54	.76	.83 (92% of corpus)
Macrolevel of argumentation	.54	.67	.7 (88% of corpus)
Social modes	.35	.55	.68 (50% of corpus), .75 (25% of corpus)
Treatment check	0	.73	.85 (97% of corpus)
Quoted	.63	.98	.98 (100% of corpus)

Although the knowledge that is brought to bear on the coding process for the 7 different dimensions has different requirements (for example, in terms of how much context is required or what the distinctions mean about the student's contribution), in all cases except the epistemic dimension the same procedure lead to a classifier that achieved a significantly higher level of agreement with the gold standard than the non-binary classifier. Thus, this evaluation demonstrates that the cascaded binary classifier has some generality.

We plan to continue experimenting with alternative classification approaches for the social modes and epistemic dimensions. Similar to our previous explorations where we clustered examples according to similarity of coding across the 7 dimensions of our coding scheme, we are now exploring the possibility of clustering the coded text segments according to similarity of vocabulary distributions within text segments. We predict that within clusters of similar texts, there will be a smaller number of categories for each dimension than over the whole set. Thus, we predict that training a classifier over just the examples within clusters will be more accurate.

DISCUSSION

We have presented and evaluated technology for streamlining the process of multi-dimensional analysis of the collaborative learning data. We have argued that such technology could potentially have a tremendous impact on this increasingly important part of CSCL research. Beyond this community a wide range of other behavioral researchers including social scientists, psychologists, and other learning scientists and education researchers collect, code, and analyze large quantities of natural language corpus data as an important part of their research.

One important outcome from this research is that even sophisticated coding schemes such as the 7 dimensional coding scheme discussed here that requires several weeks of intensive training for a human to apply reliably can be largely automated. 4 of the 7 dimensions (i.e., macrolevel of argumentation, reaction, treatment check, and quoted) can be applied fully automatically with an acceptable level of accuracy, as measured using a cross validation methodology over our gold standard coded corpus. Significant portions of the additional two dimensions (microlevel of argumentation and social modes) can be applied fully automatically to a significant portion of the data, thus cutting down the number of examples that must be coded by a human (an 88% reduction in the case of microlevel of argumentation dimension and a 25% reduction in the case of social modes dimension). While the results with epistemic dimension were lower, and the Kappa value over the whole set of data was only .51, the percent agreement was 80% over the portion of the corpus that received a committed code. This is 30% higher than the break even point for time savings with checking and correcting automatically coded examples according to Rosé and colleagues (submitted). Thus, even with this level of accuracy, the automatic category predictions can lead to a significant reduction in coding time on the epistemic dimension.

Another important outcome from this research is that the cascaded binary classification approach, which we explore, has some generality across multiple dimensions of our coding scheme although they are quite different in terms of the types and numbers of distinctions that must be made. Thus, it is an approach that is likely to be reused successfully with other coding schemes and eventually be part of an eventual approach to automatic selection and tuning of machine learning approaches to applying categorical coding schemes.

Beyond improvements to the data analysis that is central to our process, automatic coding technology would also enable new kinds of instructional interventions. For example, automatic on-line analysis of chat interactions could provide instructors with the capability to monitor the progress of multiple interactions occurring in parallel, indicating where the instructor's intervention is most needed, and even what the specific needs are that should be addressed. Further ahead, a fully automatic system could also enable automatic adaptive interventions for collaborative learning. Those interventions would be more flexible/adaptive than current static interventions. For example, a collaboration script for argument construction could be strategically applied when learners do not ground and warrant their claims and it could be faded out carefully when learners develop internal cognitive scripts that guide their argumentative knowledge construction. Such a system could prevent effects like over-scripting (Dillenbourg, 2004) or negative interaction effects between scripts (Kollar & Fischer, 2004).

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A Study of the Foundations of Artifact-Mediated Collaboration

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Abstract. The premise of this work is that, like language, the meanings of written representations are contextual and their affordances are appropriated in sometimes-unexpected ways. This situation presents a dilemma for designers of collaborative learning technologies: there is a need for representational and interactional tools that guide and support learning through cognitive and social activities, but predefined mappings between interface elements and functionalities may be too rigid. The study reported in this paper attempts to address this dilemma by identifying the strategies that people communicating via flexible written representations use to manage their interaction, and how they appropriate the affordances of media to carry out these strategies. We analyzed how people appropriated paper-based tools for collaboration under conditions approximating online interaction. Regularities were observed in the use of limited but polymorphic repertoires for communication and expression of attitude, functional and coordinative use of space, the presence of simultaneous threads, and strategies for interruption and context setting. The results suggest a new generation of collaborative technologies that include support for multi-faceted and parallel interactions, lightweight tools for expressing attitude, context representations, and scaffolding for automatically detecting and supporting emerging conventions.

Keywords: Descriptive Studies, Video Analysis, Interactional Practices, Representational Affordances, Shared Workspaces

INTRODUCTION

Studies of spoken language have established that the meanings of utterances are contextual and negotiated only to the level of agreement needed to support action. The premise of this work is that the same is true of nonlinguistic representations. Meanings of representations are not fixed in advance, but change according to context. Efforts to provide users with a visual language for reasoning or argumentation have often encountered difficulty creating a functional notation (van Bruggen & Kirschner, 2003) and in getting people to adopt such a notation (Conklin, 2003; Selvin, 2003). Also, users resist the very idea of categorizing their thinking, although they do seek representational aids in organizing ideas (Shipman & McCall, 1994). People make flexible use of representations, and the perceived affordances (Norman, 1988) of representations are appropriated in sometimes-unexpected ways. For example, Dillenbourg & Traum (1999) had participants use synchronous chat and an electronic white-board in a MOO environment while solving a murder mystery. They expected that the white-board would be used for disambiguating spatial references through its two dimensionality and drawing affordances. Instead, the most important affordance of the white-board for participants turned out to be its persistence: information that had to be recorded permanently was written in the white-board.

This situation presents a dilemma for designers of computer supported collaborative learning (CSCL) or collaborative work (CSCW) systems, or indeed computer-mediated communication (CMC) in general. (We will refer to these collectively as collaborative technologies.) There is substantial work on replicating the properties of face-to-face (FTF) communication by using high bandwidth video and audio, and techniques such as clever placement of cameras and screens for accurate conveyance of gesture and gaze (e.g., Kato *et al.*, 2001). Yet, others believe that collaborative technologies offer unique opportunities (Dillenbourg, in press) and should go "beyond being there" (Hollan & Stornetta, 1992) by exploiting the special properties of computational media in ways that make distance interaction more effective. This message resonates with educators' recognition of the need to guide and scaffold learning. Whether the application is intended for learning or work, it is not enough to simply attempt to provide a channel of communication as rich as face-to-face communication. We truly realize the potential of these technologies only if we use them to guide and enable more effective learning and problem solving practices. This point applies equally well to face-to-face interaction. If the richness of FTF were sufficient to solve problems of learning and collaboration, we would not see interest in technologies that support these activities specifically in FTF contexts.

The dilemma manifests when designers try to build representational and interactional tools that guide and support cognitive and social activities. User interfaces tend to define rigid mappings between GUI elements and functionality. Software tools that are easy to build with typical GUI toolkits are not a good match to the flexible nature of human communication, nor do they adapt to the changing needs of the user. Constrained representational tools may guide learners in their enculturation to a new field, but must be kept simple for this learning period and this simplicity may soon become too constraining. Conversely, a set of tools that is sufficiently complex for supporting experts in a field can be daunting, and dissuade novices

The present study attempts to address this dilemma by identifying how people appropriate flexible representations to meet their needs—essentially, to identify what Garfinkel calls “member's methods” (Garfinkel, 2002) for synchronous collaboration via written representations—so that we can build CMC tools with affordances that support the kinds of flexibilities observed. Like Sacks, we are “trying to find the machinery” (Sacks, 1984) of a kind of social interaction. Whereas Sacks focused on conversation in naturally occurring interactions, we are focusing on the mechanisms of intentional collaboration via written media. Despite these differences, we claim that it is valid to treat these interactions as locally-managed and socially constructed. We want to answer such questions as: When people communicate via written means, what strategies do they use to manage the interaction? How do they appropriate the affordances of media to carry out these strategies? How can our CMC tools provide those affordances while also offering task-specific guidance? This paper addresses the first two questions empirically and discusses implications for the third.

We cannot adequately answer such questions with studies of CMC, nor of FTF interaction alone. A third strategy is needed and taken by this study. We cannot effectively conduct the study with an existing CMC technology since any CMC technology we chose would carry with it the very assumptions of collaborative technology design that we are questioning. Exploratory development of collaboration technology is another alternative, but comes with a high cost of implementing each iteration of the software. It would also be a mistake to conduct the study with unrestricted FTF interaction because there are too many differences between FTF and communication technologies to create a reasonable mapping from one to the other. FTF interaction includes many subtle cues that are difficult to replicate online, and we want to find the special advantages of artifact-mediated communications that might not be evident in FTF interaction. Therefore we take a middle road. Our strategy is to start with FTF, but restrict or remove some of its features that are especially hard to replicate online and add other features such as persistence that are advantageous online. We require that people communicate with written representations, but do so using very familiar and flexible tools -- paper office supplies—so we can get a sense of which affordances of flexible representational tools participants take up, and for what communicative functions. Many attributes of the tools were varied so as to highlight invariance in communicative functions across different permutations. In this paper we report on the range of ways in which the tools were exploited and on the mapping between actions on tools and communicative functions, and discuss implications for design.

METHOD

The purpose of this study was to discover strategies or methods that people use to collaborate through shared written representations. This understanding is sought both independently of and in reference to the representations used: We want to know what kinds of communicative or coordinative functions people consistently attempt to implement independent of the representation used, and we want to know how people appropriate the affordances of specific representations for these purposes. Our methodological strategy is to vary the representational tools provided and look for invariants across the different situations. This differs from an experimental design, which attempts to control as many factors as possible and show there is a difference between experimental groups correlated with the one thing that varies between those groups. We are not making comparisons between experimental groups, and the variation in participants and materials between the sessions is desirable, as it strengthens claims of generality. Our method also differs from the micro-analysis of typical Conversation Analysis. This study focuses on identifying interactionally constructed mechanisms. Understanding the details of how the mechanisms are actually constructed is left for later work.

Participants

The study involved six pairs of friends recruited from community college and university students. Their ages ranged from 18-24, with an average of 20.9. They had a diverse set of majors, including Digital Art, Nursing, Environmental Studies, and Computer Science. Every pair except one had known each other for multiple years and all had consistent social contact. An additional six pairs were recruited for pilot studies. Unless noted otherwise, the observations below do not include data from the pilot studies.

Environment

Figure 1: Study Environment

A large table was prepared with a screen suspended above it such that participants seated on opposite sides of the table could not see each others' faces (see Figure 1). The seating was arranged such that participants could reach and therefore manipulate the entire workspace.

A video camera was placed above and to the side of the participants, positioned in the same plane as the screen to minimize the extent to which the screen blocked the camera's view of the workspace. The camera captured both participants and the entire workspace, except for a thin line blocked by the screen. Digital video output was streamed to a hard drive in real time.

Materials

In all cases, the table was covered with a secured sheet of butcher paper. All pairs had access to tape, rulers, scissors, string, paperclips, and sticky labels, dots and stars, and all pairs were provided with the same collection of various writing utensils, including red, green, blue, and black white board markers and ball-point pens, and blue and black permanent markers.

Different pairs were provided with different kinds of paper products. Three pairs of participants were given unrestricted amounts of office supplies such as varying sizes and colors of paper, multiple sizes of index cards, and multiple sizes and colors of Post-It(tm) (sticky) notes. One pair was only given 3x5 inch index cards. Two pairs were given a single, large sheet of 2x3 foot unlined paper. The original intent was to have two pairs for each condition, but after the first study session using only 3x5 cards, the data from the unrestricted office supplies appeared more promising.

Office supplies were chosen partially for their familiarity. It was assumed that participants would not need time to learn their affordances. Also, office supplies have a demonstrated history of versatility and effectiveness. The three sets of materials were chosen for the specific affordances they provided. Individual pieces of paper and index cards can be moved around and repositioned is relation to each other, and Post-It(tm) notes can be attached and detached from other materials. The index card only condition removes the attachment affordance, while the large sheet of paper disallows repositioning the participant’s contributions.

Procedure

Pairs of participants were given discussion topics, and asked to brainstorm ideas, discuss them, and come to some kind of final agreement. The pairs were given three topics chosen from a pool of five "wicked" (Rittel & Webber, 1973) problems, such as: How do we preserve Hawai'i's environment? Space aliens are coming; how should we respond when they arrive? What is the appropriate relationship between science and religion? Wicked problems are typified by the lack of clear evaluation metrics for any answer as well as the lack of a well-specified process for approaching them. This required the participants to collaboratively develop processes for collaboration and evaluation, and to negotiate when they had come to the end of the interaction. The order and selection of topics assigned to the pairs were permuted to create the greatest variability.

Every effort was made to support the greatest amount of flexibility in the representational medium. One the other hand, several restrictions were placed on the participants in order to approximate limitations of online communication. Since current online communication is predominantly text-based, we chose to limit visual and verbal channels. Participants were required to communicate entirely through the use of the pens and materials, and because of the screen, participants were unable to communicate using facial expressions. They were also asked to remain silent while working on the assigned problems. The participants' hands and arms were visible to each other. Given that deixis is so fundamental to communication, and since tele-pointers and avatars are viable CMC tools, this seemed to be a reasonable allowance.

Problems were printed on sheets of paper and given to the pairs one at a time. Pairs were allowed to ask for clarification about the problems before they began each session. They were told that they should collaboratively analyze the problem in as much detail as possible, and that they needed to come to a final conclusion they both agreed on. Pairs were given 30 minutes to work on each problem. The experimenter kept notes on his observations during the study sessions. After each problem the pairs were interviewed on their conclusion, what they thought of the interaction, difficulties or issues with the procedure, and any other reaction to the session. The experimenter also used this time to verify his interpretations of the session activities.

Analysis

The video data was analyzed in multiple passes. We approached the video with no predefined theory or system, and made every effort to let the data guide the analysis. A custom application was developed to support variable speed review of the video and a simple annotation system. Initial review of the video was done at normal speed, to reinforce awareness of the contents, and then at double or triple speed to get a sense of the larger-scale recurring patterns. Initial reviews of the video identified several of the most obvious interaction patterns—generally those that dealt with use of the space and interaction structure. Successive reviews looked specifically for these patterns and identified several more. The entire collection of video (approximately 8 hours) has been reviewed multiple times, and several interesting segments have been studied in more detail.

OBSERVATIONS

With the exception of one pair, all the participants reported that while it was constraining to communicate with only the written word, they still felt they were able to communicate successfully. One participant in the pilot study reported that he actually preferred the written format in some ways because it was harder to be interrupted by the other participant. The S5* pair was an exception. This pair evidenced a high degree of interpersonal conflict, and didn't come to agreement on any of their three topics. The observations reported below exclude the S5 pair. A summary of their interactions is provided later.

In this analysis, we were specifically looking for patterns related to the mechanics of collaboration, and not the content of the interaction nor the practice of sense-making (which may be considered in future analyses). After some general comments about the structure of the interactions, we describe six categories of specific mechanisms that we identified: Functional Spaces, Simultaneous Threads, Placement, Interruption, Setting Context, and Repertoire.

Structure of Interactions

The interactions all resembled informal conversations. Topics and ideas introduced by each participant were explored only to the point where the two participants agreed on either the topic's relevance or a general conclusion. Few topics were revisited, and usually only to verify agreement before the information was incorporated into the final product.

The content displayed a topically episodic structure. The participants moved back and forth between simultaneous individual work and collaboration. Collaborative interactions were usually initiated by one participant, and consisted of contiguous contributions (possibly in parallel with other activity) until the topic was resolved. The resulting artifacts reflect this structure. On a single large sheet of paper, areas can be identified for each topic addressed. Pairs who used 8.5x11 pages generally confined each topic to a single page, and pairs who relied on smaller materials almost always introduced a new post-it or 3x5 card to start a new topic.

There was no evidence of complex information management. For example, the physical nature of the materials was not exploited to investigate connections between ideas or to propose categorical groupings or inclusions.

Functional Spaces

Every pair used some mechanism to separate the text of the argumentation from the text of the conclusions. Once these spaces were designated, participants resisted altering their purpose. In several cases the pair continued to squeeze the argumentation text into a constrained area long after this stopped being possible without interfering with the prior record. One pair in the single large sheet of paper condition split the paper into a "Work Area" (~30%) and a "Plan" (~70%) area (see Figure 2). When the "Work Area" had been completely filled with text, the "Plan" area was still almost completely unused. Rather than re-designate space from the "Plan" area, the participants used larger markers to write over the top of the existing text in the "Work Area". This behavior was not unique. Many pairs constrained their contributions to an impractical writing area while leaving large areas designated for results unused.

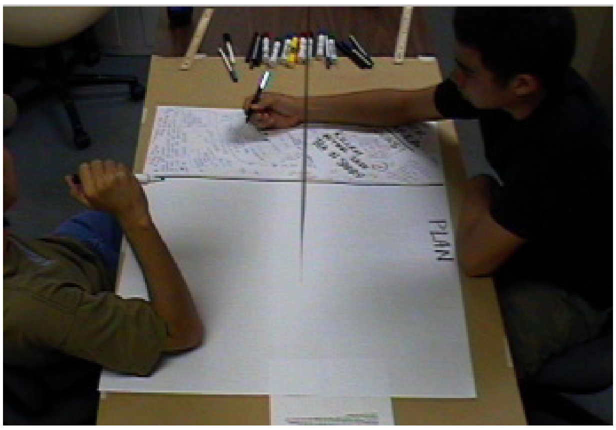

Figure 2: Functional Spaces—the work area is full, while the area for conclusions remains unused.

* The sessions and participants are identified by codes. S5 identifies the fifth pair to participate. S5L and S5R respectively identify the participants sitting on the left side and right sides of the table in relation to the camera.

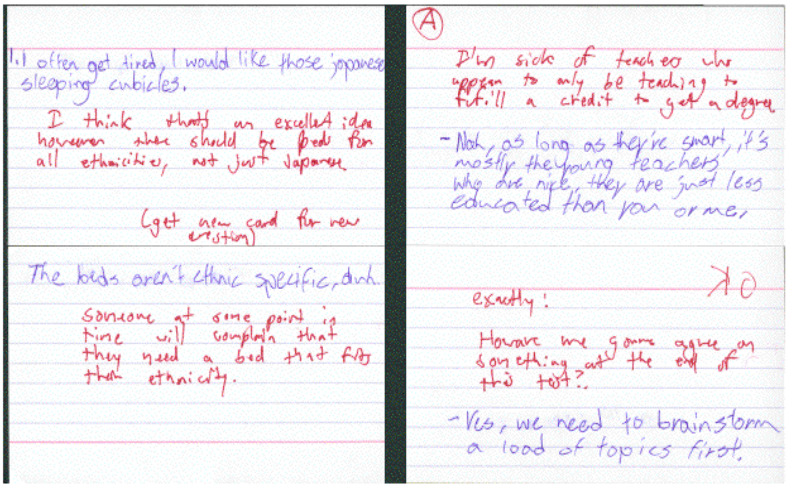

Figure 3: Simultaneous Threads—The participants used different pen colors. These cards were exchanged repeatedly.

Simultaneous Threads

The nature of the materials afforded simultaneous contributions from each participant. The large sheet of paper provided ample space for both participants to write concurrently. Smaller, individual pieces of paper allowed each participant to have their own writing area.

In all but one pair, there were frequently two concurrent threads of contribution. When participants used materials that could be positioned (i.e. sheets of paper, 3x5 cards, etc.) each piece of paper usually represented a single topic thread. The pair would alternately write on the paper and then pass it across the table to their partner (see Figure 3). This had the added benefit of indicating when each person was done writing, and produced a spatially coherent artifact oriented to the topic. Participants using a single large sheet of paper tended to group contributions to a thread, but occasionally participants in this condition carried on synchronous threads by alternately writing on the paper as close to their partner as possible (i.e. on the far side of the table from themselves). This resulted in several topic threads that were not at all spatially coherent, but this didn't appear to interfere with the interactional coherence of the exchange. More often, though, topics were confined to a specific area on the paper, and there are easily observable spaces between the areas for each topic.

Pair S3 was an exception. Each maintained their own material to write on, and would alternately write and then read what their partner had written. They didn't reorient their material so the other could read it—they consistently read the other's text upside down. The S3 pair consisted of members of the deaf community, and while this use of the materials resembled a common practice in that culture, the participants reported that the usage was not a conscious choice. This use of the materials produced interactions consisting of a single thread, with each contribution alternating between separate pieces of paper.

Pairs using mobile materials tended to keep related information on a single piece of paper. When a participant made a contribution to an existing thread, he/she did so by adding the contribution to the piece of paper that contained that thread. On the single large sheet of paper, text ran in all directions, and while related contributions were usually added near the related text, there was occasionally no space to add a contribution. In this condition, pairs made use of lines and arrows to connect their contribution to previous text. These connecting arrows were sometimes used even when the contributions were in proximity to each other or the connection was obvious.

Pairs displayed no cognitive difficulty in managing multiple topics. The simultaneous topics on the different 3x5 cards remained coherent, and the participants displayed no difficulty keeping track of conversational threads. On the large sheet of paper, participants had no difficulty being interrupted during an individual contribution to focus on their partner's topic. The interrupted party went back to his/her individual work with no problem.

Placement

The pairs using multiple materials made remarkably consistent use of position and placement. The tabletop workspace allowed objects to be moved around and overlapped. Unsurprisingly, every pair in these conditions consistently contributed to the current topic using the space directly between the two of them. Objects that were no longer current were set to the side.

More interestingly, participants positioned objects between themselves so as to mediate access. Individual contributions were consistently made with the object close to the writer. A standard pattern was for the writer to position a card close to his or her self, write a contribution, and then move the

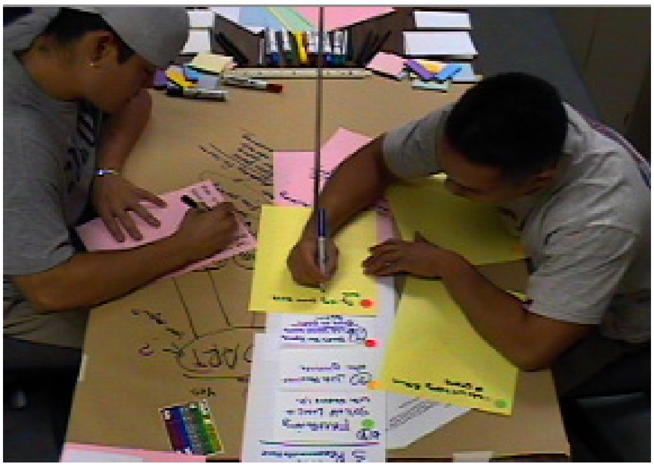

Figure 4: Placement—the participant on the right is adding to the conclusions, while his partner is starting a new topic.

card to the other participant’s side of the table. The position also regulated the contributions of the writer's partner. When a material was in the center of the table, both participants would regularly write words and complete sentences on it. When the material was close to one participant, however, the other participant limited their contributions to pointing or tapping or writing individual symbols, most often a question mark.

The more collaborative interactions took place nearer the center of the table (see Figure 4). When the two participants were engaged in negotiating an agreement, the interaction often took place on a single piece of paper positioned in the center of the table. The shared paper was turned repeatedly so each participant could write easily, but participants tended to orient the paper sidewise, allowing each participant the same ability to read and contribute, and rarely moved the paper closer to their own side of the table. Papers used to record conclusions or final results also often stayed near the center of the table and usually remained oriented sideways. This sideways orientation of the shared conclusion was also used in one of the large sheet of paper conditions.

Interruption

All the pairs used a similar protocol for interruption. To get the other's attention, a participant would touch the other person on the arm, or tap repeatedly on some text. These interruptions were often not responded to immediately. Participants were able to queue the request for attention until they were done with their immediate task. This usually meant that the person would finish writing a sentence or conclude a thought. Usually, the person making the interruption did not insist on an immediate response from their partner. After a participant had requested their partner's attention, they would often go back to work until the partner finished their task and changed focus.

Setting Context

When the members of a pair were working individually, and one of them wanted to engage the other, two specific behaviors were used for setting the current topic.

When a new topic was introduced, a participant would usually write an initial sentence and then bring it to the attention of the other participant before continuing. With materials that afforded positioning, this generally involved the writer moving the material to their partner's side of the table. Several mechanisms were used to negotiate when materials could be exchanged or moved. Either the participants would wait until they were both done writing and then swap materials, or the writer would place the material on their partner's side of the table, sometimes intentionally obscuring the partner's current work. With a single sheet of paper, the writer would produce the introductory sentence, get their partner's attention, and then tap the new text. This was often followed by the writer running a finger under the text, indicating what the partner should read.

When a participant wanted to return to a previous topic, the order of actions was reversed. The participant would indicate previously written text by tapping on it or underlining it, and then write a related sentence. This related sentence sometimes did not need to be in proximity of previously written text. Participants had no problem understanding that the underline was meant as an indicator, and not for emphasis. When the participants re-read the text later, they did not appear confused by the underlines or other markings that had accrued.

Repertoire

Despite the availability of a wide variety of materials, every pair constrained themselves to a very limited subset. Even when the widest variety of materials was made available, all pairs tended to use only one or two materials almost exclusively. New types of materials were generally introduced to distinguish types of information, i.e. in a session recorded entirely on 3x5 cards a pink post-it was used to record conclusions.

In addition to limiting their choice of materials, all the participants made use of a remarkably limited set of gestures, deixis, and symbols. Women were considerably more likely to use hand gestures than men. Still, these gestures were mostly limited to an approval gesture (e.g. thumbs up) and a questioning gesture (e.g. hands spread palm up, like what usually accompanies a shrug). Actions that related to the artifact consisted of a variety of pointing gestures. Participants pointed at, tapped on, or ran a finger along (under) artifact elements. Gestures involving both hands were apparent, e.g. indicating some written text with one hand, either pointing, tapping, or underlining, and then tapping the area being used to record conclusions with the other hand

A similarly limited number of symbols were employed in the written artifacts. Symbols were almost never used independently, but almost always as an annotation or in reference to some other piece of text. The symbols used regularly were question marks (by far the most prevalent), arrows, smiles, stars, and check marks. Two different pairs of males each drew representations of a hand with the middle finger extended, but only once each. Despite a variety of labels and stickers, pairs only made use of stars and colored dots.

Actions, gestures, and symbols were polymorphic. Pointing, for example, might be used to indicate suggested topics, related information, reminders, request for clarification, or illegible handwriting. Participants used underlining to indicate emphasis, to relate the current discussion back to previous discussion or the problem statement, to set the context of a subsequent contribution, and to indicate repetition. The meaning of question marks and other symbols were similarly context-sensitive.

Conflict

The sessions were remarkably consistent in the high degree of collaboration, the success of arriving and shared conclusions, and the use of similar mechanisms. The S5 pair was an exception. They displayed a high level of hostility towards each other, and they failed to arrive at a conclusion to any of their three topics—the only pair to fail to do so.

The two women had very different demeanors. S5L was very aggressive while S5R tried to be more conciliatory. S5L tended to make long, individually produced contributions, but then gave short, negative responses such as "no" or "who cares?" with a considerable amount of underlining. The most interesting aspect of the pair's interaction, however, is that the communicative methods they used were consistently the reverse of the other pairs.

Rather than the episodic structure seen in the other pairs, the S5 pair would pursue a topic only until there was a conflict at which point S5L would usually turn the material over or introduce another piece of paper and start a new topic. S5L tended to ignore her partner's interruption requests, but was insistent that her own be attended to immediately. The pair never settled on a specific place for conclusions. S5R tried to designate such a space, but S5L did not adhere to that designation. In one session, S5R attempted to maintain interaction on a centralized sheet of paper, but when S5L contributed, she would pull the paper to her side of the workspace and halt the interaction by writing long tracts of text. During another session, S5L would often reach across the table and write whole sentences. One entire segment takes place on S5R's side of the table.

It is interesting that the only pair that did not display many of the coordinating mechanisms just discussed also displayed a high level of conflict and lack of success. In this sense, S5 is the exception that proves the rule.

DISCUSSION

Despite all the variation introduced into the study sessions, there is considerable evidence of consistent communicative needs and methods for meeting these needs. This consistency spans differences in topics, materials, and individuals. That these methods were consistently recreated indicates something about the importance of these needs. Implications of addressing these needs in a CMC environment will be discussed further below.

Some environments provided affordances that naturally mapped to a specific task, e.g. relating two ideas by placing them in proximity with each other. In the conditions where the materials did not provide these natural affordances, participants did their best to approximate them. For example, on the single large sheet of paper arrows were used to approximate collocating related ideas. While pairs with multiple materials tended to reserve specific papers for their results, in the single large sheet of paper condition people approximated this by marking off areas reserved for conclusions. The methods participants developed were certainly driven by the affordances of the materials they were using. However, the fact that pairs given less appropriate materials approximated methods by appropriating the available affordances implies that they weren't just responding to the environment as it was given to them, but that they had some idea of specific communicative methods that they felt were required.

These observations might lead one to the conclusion that the specifics of the environment make little difference. It is possible that given any environment, people will create tools appropriate to the environment, adapting to the limitations of their tools and "making do" with whatever affordances are available in order to perform important communicative tasks. Conversely, it might be argued that we could determine the "best" affordances, and simply ensure that any collaborative environment supported them. However, the effectiveness of an affordance cannot be judged in isolation. Different affordances and groups of affordances will map more "naturally" to different activities. A comparative approach should be taken to determine how collections of affordances more effectively support any specific collaboration method.

Support for Complex Interaction

Flexible Topical Structure

The pervasive use of multiple, simultaneous topics threads mirrors the kinds of interaction being studied in multi-user text chat environments (Herring, 1999; O'Neill & Martin, 2003) O'Neill and Martin make the case that temporal proximity is not as important as interactional coherence, and that participants in a text chat environment will develop mechanisms for repairing misunderstanding. In fact, they found that rather than being limited by the lack of temporal proximity, participants incorporated it into their communication as a source of humor. Like people using text chat, participants in our study were able to maintain interactional coherence via the affordance of persistence rather than strict alternation of contributions. Similarly, the text of contributions was not constrained by direction, succession, or strict alternation. Participants made full use of the ability to add contributions with minimal regard to format despite the fact that this produced messy, complex workspaces. These kinds of expressive freedom should be explored in the next generation of collaboration tools.

Managing Multiple Topics with Interaction Contexts

The overall structure of the interaction followed a sort of stream-of-consciousness series of topics. There was no advance organization or agenda setting. Instead, the participants responded to each other's contributions as they were brought into the workspace. Rather than imposing a mechanism for ordering and managing topics, the participants managed their focus on each topic through the affordances of the physical workspace.

Participants seemed to move the various topic threads between several states. Participants used position and orientation to invite a response, to initiate collaboration, or to indicate ownership (and the corresponding limitation on their partner's contributions). This happened with multiple topics at a time, indicating a model of discourse that is less linear and instead relies on opportunistically advancing elements of the overall interaction. Collaborative software could support this model by providing better management of multiple topics including simultaneous awareness of the state of each. These observations also suggest a collection of loosely defined "soft" workspaces, each representing a context of interaction that includes topic information as well as affective information and the current participant expectations. The software to support this would have to support a simple mechanism for switching attention from one topic to another as well as merging and branching the contexts.

Prioritizing Contributions

Not all contributions are of equal importance. The use of interruption indicates that participants want to bring some contributions to their partner's attention immediately, while others can wait until the partner is available. Within the confines of the synchronous environment, there seems to be some variability in just how synchronous an interaction needs to be. Collaborative software could support this management of prioritization by providing mechanisms for passive contributions to a shared artifact along with more proactive tools that alert participants to certain contributions as they are being made.

Ease of Indicating Attitude

The majority of contributions to any session fell into two categories: contributing new information and indicating an affective response to that information. Topics were addressed just until both participants had indicated (dis)agreement or (dis)approval, not until they had been exhaustively examined. Each participant used the ability to quickly express an affective response as a recurring tool to help shape and direct the interaction. It is notable that participants indicated attitudes with symbols and hand gestures rather than written out sentences. The ability to easily and continuously express attitude is fundamental to conversation, but generally absent from current collaboration technologies. Even the use of emoticons and similar tools requires a conscious mapping of response to representation.

For the participants, the affective layer of information took the place of thorough data analysis. In the artifacts there is a wide variety of content types, but there is a notable absence of any sort of organizing mechanisms. Aside from defining work and conclusion spaces, there are almost no explicit rating systems, pro and con lists, or inter-relation between the topics. Since indications of approval and agreement were often made with non-persistent actions, the participants were required to remember the status of the various topics and of the interaction as a whole. Without a visible record, both participants would have had to assume that they were each remembering things in the same way. There's an upper limit on the complexity of data managed this way. After a certain point, it becomes necessary to impose some organization so the information can continue to be used effectively. Although collaboration technologies can help with this, fixed organizational schemes would carry with them the problems of inflexibility that motivated this study. We should explore collaboration technologies that automatically infer the implicit organization from affective contributions and artifact manipulations, and facilitates the application of this organization as the need becomes apparent.

This discussion suggests two important limitations of this study; the limited time frame and the dependence on personal opinion and knowledge (rather than external data and/or formal evaluation criteria). It is possible that a longer time frame or the requirement to use external information and formal criteria would have motivated participants to invent more organizational mechanisms. Also, writing all contributions by hand limited the amount of text that could reasonably be generated in 30 minutes. This seemed to dampen enthusiasm for extended debates or long explanations.

Simpler Tools, Emergent Conventions

The participants in this study only developed a small number of communicative methods, and once a participant pair chose a material or method, they tended to use it for the duration of the session. Even when the method was found to be inefficient, or they agreed on its limitations, they fell to using it again for the next topic. Similar self-constraint on the use of available materials and tools has been documented in usage studies of complex software such as word processors and spreadsheets. (Nilsen *et al.*, 1993) notes that users only learn a subset of the application's functionality—usually just enough to accomplish their normal tasks. It is possible that fewer yet more flexible tools in collaborative software might encourage users to make more creative and personalized use of the environment.

There is a similar self-imposed limit on the use of notational conventions. In the few cases where conventions were attempted, they either quickly became confusing, were immediately ignored or miscommunicated between the participants. The effort of remembering and applying a convention outweighed its perceived value. Collaborative technologies should be designed to reinforce the use of notations by allowing conventions to emerge from the interactions without them being explicitly defined.

User-Driven, Complex Actions

Polymorphic Actions

In contrast to the limited number of actions, the communicative functions performed were numerous. Every action was used for multiple purposes. Actions such as pointing, underlining, and drawing an arrow do not by themselves have concrete semantic content or indicate a specific communicative function. Each of these takes on meaning given the context in which it is used. Each of these actions could be combined and overlapped with other actions as well as modified, giving rise to the wide range of meanings we observed. For example, tapping on a piece of text that one has just written draws attention to the new contribution, while tapping on text just written by one's partner may indicate agreement, or if followed by further writing may indicate the intent to comment. These combinations were additionally modified based on the interactional context in which they occurred. The position or ownership of the indicated text changes the meaning of the writing that followed. Finally, the nature of these composite actions was additionally modified by the perceptible attitude of the person who was performing them. The speed or intensity with which the actions were performed further extended the already broad palette of possible communicative acts. For example, a participant may have tapped more gently to show agreement or more energetically to show insistence.

Despite polymorphism, the intention of each action was almost never misconstrued. Rather than create any formal definitions, participants were willing to expend the mental effort to perform continuous (re)interpretation of these actions and their context. For example, post-interviews with the S6 participants revealed that even when there was an awareness of a mismatch in interpretation (P1 knew that P2 had misunderstood the meaning of a notation used by P1), the participants preferred to revise their understanding of each other's behavior rather than produce external documentation (P1 interpreted P2's actions in light of the misinterpretation).

The number of possible meanings accessible to the participants could not be reasonably represented using the typical "single tool = single meaning" paradigm available in existing user interface development toolkits. We should investigate the creation of simple, flexible tools that support creative combination and repurposing. Allowing users' own repertoires of symbols and actions to emerge from their interaction will give rise to richer and more actor appropriate tool sets.

CONCLUSIONS

This study was conducted in an environment significantly different from either typical conversation or typical on-line communication. Face-to-face conversation is generally not persistent, and relies heavily on a wide range of non-verbal cues. Typical online environments provide a structured set of tools to facilitate communication, but don't support complex gesturing or physical interaction. This study environment attempted to marry the limited communication channels of the online environment with the flexible representational abilities of pen and paper. Participants' level of engagement suggests that this marriage was successful.

The data gathered from this study shows a great deal of consistency at the structural level of artifact-mediated communication. Analyzing interaction from the bottom-up gives a sense of how people act "naturally" and suggests several possible implications for the design of collaborative systems. A new generation of collaborative technologies could include support for multi-faceted and parallel interactions, lightweight tools for expressing attitude, context representation, and scaffolding for automatically detecting and supporting emerging conventions.

This study should not, however, be taken too literally as a design for an online environment. Some of these behaviors are deeply tied to the physicality of the workspace, e.g. managing placement and orientation of materials, using both hands for gesturing, or touching to get one's attention. A direct implementation of this environment would have difficulty reproducing this physicality and at the same time fail to take advantage of abilities afforded by the electronic medium (Dillenbourg & Traum, 1999; Hollan & Stornetta, 1992). Instead, we should recognize that communicative and representational practices emerge from interaction. This study demonstrates the emergence of powerful, context-specific mechanisms in underconstrained collaborative interaction. As Suthers (2005) proposes, the appropriate next step is to iterate over a series of software designs, evaluating each in terms of a qualitative understanding of how the affordances each makes available influence and facilitate users' collaborative processes.

People make sense of the world through interactions based on their perception of how objects allow them to act, not necessarily a contemplation of the objects' purpose. Action occurs in the instant-to-instant process of perceiving and responding to the world, not in an abstract vocabulary of models and operations. Providing users with complex manipulation tools might, in fact, be less important than providing effective context and information presentation (Button & Sharrock, 1997). In the long run, one of our challenges is to determine how collaboration technologies can make the best use of computational resources and most effectively leverage the processes of sense-making already taking place in the minds and interactions of our users.

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Effects of an Individual's Prior Knowledge on Collaborative Knowledge Construction and Individual Learning Outcomes in Videoconferencing

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Abstract. This paper deals with collaborative knowledge construction in videoconferencing. The main topic for investigation is how to predict individual learning outcomes, and in particular the degree to which an individual's prior knowledge and collaborative knowledge construction can influence individual learning outcomes. In this context, the influence of prior knowledge and two measures of instructional support, a collaboration script and a content scheme, were analyzed with respect to collaborative knowledge construction. An empirical study was conducted using 159 university students. Students worked collaboratively in groups of three within a case-based videoconferencing learning environment and were supported by instructional support measures. Results indicated that collaborative knowledge construction had a greater impact on individual learning outcomes than an individual's prior knowledge.

Keywords: prior knowledge, factual knowledge, applicable knowledge, cooperative/collaborative learning, teaching/learning strategies, videoconferencing, collaboration script, content scheme, collaborative knowledge construction, shared application

INTRODUCTION

Recently, there has been quite a lot of research on collaborative learning in computer supported learning environments (cf. Andriessen, Baker & Suthers, 2003; Bromme, Hesse & Spada, in print; Dillenbourg, Eurelings & Hakkarainen, 2001; Kirschner, 2002; Koschmann, Hall & Miyake, 2002; Stahl, 2002). In this context, most researchers focus on how learners use the learning environment, on supporting collaborative learning or on the processes involved in collaborative learning. However, research generally does not consider sustaining effects of the collaborative learning environment. This means that – even if researchers study the increase in learners' knowledge – questions about the predictors of individual knowledge acquisition remain unanswered. However, the issue of predictors is crucial for research in computer supported learning environments. Many studies are able to prove the effects of support measures during the learning process, but can prove none or only few effects on individual learning outcomes (cf. Baker & Lund, 1997; Fischer, Bruhn, Gräsel & Mandl, 2002; Pfister & Mühlpfordt, 2002; Weinberger, 2003). One reason for such results may be the influence of an individual's prior knowledge, which may negate effects of collaborative knowledge construction (cf. Dochy, 1992; Kalyuga, Chandler & Sweller, 1998, 2000, 2001; O'Donnell & Dansereau, 2000; Renkl, Stark, Gruber & Mandl, 1998; Stark & Mandl, 2002). Thus, finding predictors for individual learning outcomes can help to improve support measures for collaborative learning by focusing on relevant criteria.

This paper focuses on predictors for individual learning outcomes in collaborative net-based learning scenarios. The influence of prior knowledge and collaborative knowledge construction is investigated based on an empirical study. For further insights, the effects of support on collaborative knowledge construction are also researched, in particular the effects of a collaboration script and a content scheme.

COLLABORATIVE LEARNING IN VIDEOCONFERENCING

Collaborative learning in small groups means that groups act relatively independent of a teacher with the goal of acquiring knowledge or skills (cf. Cohen, 1994; Dillenbourg, 1999). One major goal of collaborative learning is to support social interaction and encourage the learners' cognitive processes. In this context, learners' elaborations are seen to play a crucial role (cf. Webb, 1989; Webb & Palincsar, 1996) for expressing knowledge, ideas and beliefs to their partners (cf. O'Donnell & King, 1999; Palincsar & Brown, 1984; Rosenshine & Meister, 1994): learners work to co-construct knowledge collaboratively (cf. Bruhn, 2000;

Fischer, Bruhn, Gräsel & Mandl 2000; Roschelle & Teasley, 1995). In addition, learners externalize and elaborate on learning material by taking notes (cf. Gould, 1980; Molitor-Lübbert, 1989), e.g. in a shared computer application. In collaborative learning environments, learners often create these written representations collaboratively (cf. Baker & Lund, 1997; Dillenbourg & Traum, 1999; Klein, 1999; Suthers, 2001). During this process, they create a shared external representation of the subject matter, which can be helpful for collaborative knowledge construction (Ertl, 2003; Fischer et al., 2002). When constructing a shared external representation, learners must externalize their knowledge, that is, they must elaborate on and comprehensibly explain their knowledge to their learning partner (cf. Hayes & Flower, 1980; Peper & Mayer, 1986). Furthermore, creating shared external representations can encourage learners to solve conceptual or structural problems they may have with the subject matter (cf. Fischer & Mandl, 2002; Gould, 1980; Molitor-Lübbert, 1989) and influence the co-construction of knowledge (cf. Eigler, Jechle, Merziger & Winter, 1990; Fischer & Mandl, 2002). In videoconferencing, shared applications play a prominent role in such externalization processes: The shared applications offer a shared externalization forum, which is common to all the dispersed learning partners (Dillenbourg & Traum, 1999). In computer-supported learning environments, shared applications are often built as tools for the learners (cf. Spitulnik, Bouillion, Rummel, Clark & Fischer, 2003; Suthers & Hundhausen, 2001). Such tools support the active representation of knowledge and can support learners domain-specifically (cf. Dillenbourg & Traum, 1999; Roschelle & Pea, 1997), reduce consensus illusions and foster the integration of prior knowledge (cf. Fischer et al., 2002). However, studies show that it is not enough to simply provide a collaborative learning environment (cf. Johnson & Johnson, 1992; Lou, Abrami & d'Apollonia, 2001; Rosenshine & Meister, 1994; Salomon & Globerson, 1989; Slavin, 1995). The collaborative learning process and outcomes can be improved greatly when appropriate additional support is provided.

Outcomes of Collaborative Learning

In this context, it is necessary to have a view on the conceptualization of learning outcomes. There are two main methods of assessing the benefits of a collaborative learning scenario: either individually on the learner level or collaboratively on a group level. However, there are differences in the interpretation of such learning outcomes (cf. Anderson, Reder & Simon, 1996; Greeno, 1997; Hertz-Lazarowitz, Kirkus & Miller, 1992; Salomon & Perkins, 1998; Slavin, 1995; Webb, 1989). The main questions surround the degree to which individual knowledge assessments can evaluate the effects of collaborative knowledge construction and the degree to which group assessment can indicate an individual's learning progress. Regarding individual learning outcomes, one can distinguish between conceptual knowledge and applicable knowledge (cf. De Jong & Fergusson-Hessler, 1996). According to this distinction, the term conceptual knowledge is used if learners can appropriately recite facts about the subject matter, while applicable knowledge means that learners can also apply their knowledge, e.g. in problem solving. In contrast to the clear conceptualization of individual learning outcomes, it is less clear how to measure the effects of collaborative knowledge construction on a collaborative level. In this context, Hertz-Lazarowitz et al. (1992) suggest that the product of the collaboration process, e.g. a final collaborative problem solution, should be considered as "group knowledge" or as a collaborative learning outcome. Other approaches stress the importance of learners' convergence in knowledge construction (cf. Fischer & Mandl, in press; Jeong & Chi, 1999).

Even if differences between individual and collaborative measures of learning outcomes may be attributed to characteristics of different learning tasks, the issue of the individual and social aspects of learning outcomes is of particular importance for cooperative learning in computer supported learning environments. In such environments, groups may be formed and disbanded quite quickly (cf. Walther, 1994; Walther & Burgoon, 1992). Therefore, the individual's benefit from the collaboration may become more important for the collaborating partners than social aspects of groups or the quality of collaboration (cf. Kerr, 1983). Thus, learners in such scenarios may desire maximal individual profit instead of a high quality collaborative knowledge construction. As a consequence, dysfunctional group phenomena may occur (cf. Salomon & Globerson, 1989). On the other hand, when focusing on high-quality collaborative outcomes, groups may apply strategies for maximizing group performance at the cost of neglecting group members with less knowledge. In such cases, the skilled learners may benefit quite a lot from collaboration, while less skilled learners may not benefit at all (cf. Dembo & McAuliffe, 1987; Salomon & Globerson, 1989; Webb, 1989). Thus, it is important to analyze both collaborative and individual learning outcomes when investigating group learning (cf. Salomon & Perkins, 1998).

Support Measures for Collaborative Learning

Collaborative learning in computer supported learning environments is often supported to avoid dysfunctional group phenomena, to improve the learning process and to foster knowledge acquisition. Well-known examples for such support are collaboration scripts (cf. Baker & Lund, 1997; O'Donnell & King, 1999; Pfister & Mühlpfordt, 2002; Rummel, Ertl, Härder & Spada, 2003) and content schemes, which provide conceptual support (cf. Brooks & Dansereau, 1983; Dobson, 1999; Ertl, Reiserer & Mandl, 2002; Fischer et al., 2002). In the context of CSCL, collaboration scripts aim mainly at supporting collaboration strategies by assigning different roles to the learners and by sequencing or structuring the work. In contrast, conceptual support aims particularly at improving the comprehensibility of the subject matter's structure.

Such support measures are mainly directed at collaborative knowledge construction and are thought to substantially improve the process of collaborative knowledge construction. This is reflected in many studies (e.g. Baker & Lund, 1997; Ertl et al., 2002; Fischer et al., 2002; Rummel et al., 2003). However, even if many of these studies were able to reveal effects regarding the quality of collaborative knowledge construction, there are often mixed results regarding individual learning outcomes (cf. Baker & Lund, 1997; Fischer et al., 2002; Pfister & Mühlpfordt, 2002; Weinberger, 2003). One reason for this may be the influence of an individual's prior knowledge.

THE ROLE OF PRIOR KNOWLEDGE IN COLLABORATIVE LEARNING

An individual's prior knowledge is known to be an important prerequisite for *individual* knowledge construction and learning outcomes. Many theoretical approaches stress the importance of learners' prior knowledge when acquiring new learning material (cf. Gerstenmaier & Mandl, 1995; Glaser, 1989). Many empirical studies also highlight the influence of prior knowledge on individual learning outcomes (cf. Dochy, 1992; Kalyuga et al., 1998, 2000, 2001; O'Donnell & Dansereau, 2000; Renkl et al., 1998; Stark & Mandl, 2002; Weinert & Helmke, 1998). Thus, when assessing learning outcomes, the structure of an individual's prior knowledge may negate the effects of the collaborative knowledge construction.

In research on *collaborative* learning environments, an individual's prior knowledge is mostly neglected with respect to learning outcomes. Different levels of learners' prior knowledge are mainly used to explain group phenomena (cf. Salomon & Globerson, 1989), the quality of explanations (cf. Webb, 1989) or as a control variable for ensuring that learners do not differ significantly. In studies about the support of collaborative learning, an individuals' prior knowledge often plays an important role in group composition (cf. Slavin, 1995; Cohen, 1994), while the influence of prior knowledge as a prerequisite for collaborative knowledge construction and individual learning outcomes often remains unclear. However, studies by O'Donnell and Dansereau (2000) investigating the effects of prior knowledge in collaboration indicate that an individual's prior knowledge also influences learning outcomes in the collaborative learning context. Furthermore, studies reveal that prior knowledge could interact with other factors in collaborative knowledge construction – such as instructional support measures for the learners (cf. Reiserer, 2003).

In summary, results show that prior knowledge influences individual and collaborative knowledge construction. In addition, studies indicate that there are interactions between an individual's prior knowledge and instructional support measures. To date, there have been no findings on the role of an individual's prior knowledge in the context of support measures for collaborative knowledge construction. There is also no information concerning the extent to which an individual's prior knowledge and collaborative knowledge construction may influence individual learning outcomes.

RESEARCH QUESTIONS

For gaining insights on these issues, we conducted an empirical study using the following research questions:

- *Research question 1:* To what extent does an individual's prior knowledge affect the quality of collaborative knowledge construction supported by a collaboration script and a content scheme?
- *Research question 2:* To what extent do an individual's prior knowledge and the quality of collaborative knowledge construction affect learners' individual learning outcomes regarding conceptual and applicable knowledge?

METHOD

To answer these questions, an empirical study was conducted in the laboratory of Ludwig Maximilian University. 159 undergraduate students of Education took part in this experiment.

Design of the Experiment. The experiment comprised an individual and a collaborative learning unit (cf. figure 1). During the individual learning unit, learners acquired knowledge about attribution theory on the basis of a theory text. After working on this text, the learners' prior knowledge was assessed using an individual case solution and a short-answer test about conceptual knowledge. For the collaboration, three learners were connected with a desktop video-conferencing system, which included an audio- and video-connection and a shared application. Using this videoconferencing environment, learners had to collaboratively solve a learning case according to attribution theory. During collaboration, groups of three learners worked in one of four conditions of a 2x2-factorial design. The variable factors were collaboration script (with vs. without) and content scheme (with vs. without). After the collaborative learning unit, learners' knowledge was assessed on an individual basis by asking them to solve a case and complete a short-answer test.

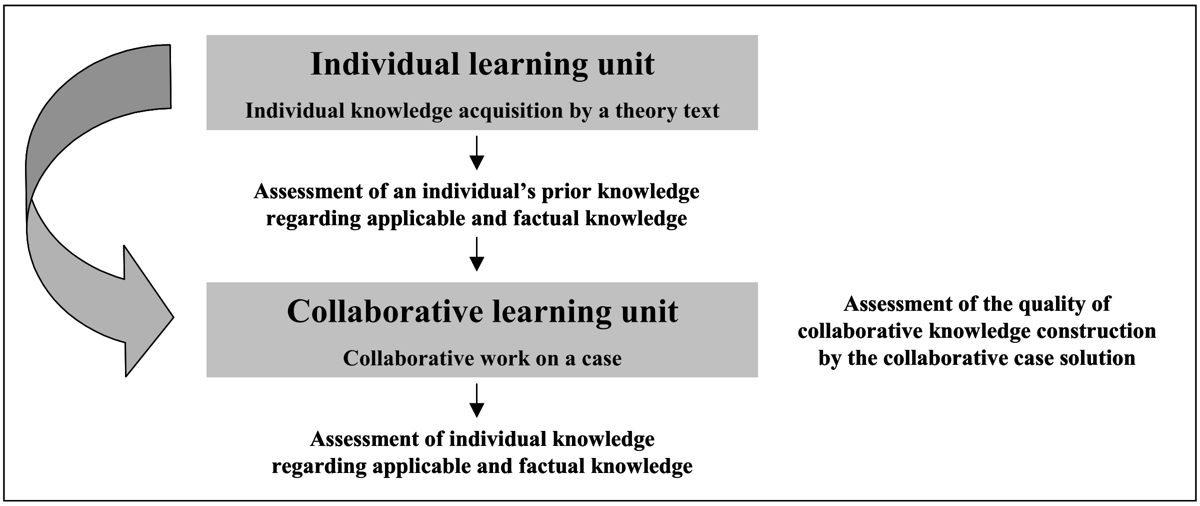

Figure 1: Design of the experiment

As instructional support for collaborative knowledge construction, a collaboration script, a content scheme and a combination of both were used and compared with a control condition. Both the collaboration script and the content scheme pre-structured the collaboration.

The *collaboration script/no content scheme* condition (13 Triads) structured the collaborative unit into four phases. In the *first* phase, learners had to read case material and extract important information on an individual basis. In the *second* phase, learners had to exchange information and resolve comprehension questions collaboratively. They used the shared application for writing down concepts that were important for the case solution. In the *third* phase, learners had to reflect individually and in the *fourth* phase, learners had to collaboratively develop the case solution.

The *no collaboration script/content scheme* condition (14 Triads) pre-structured the shared application that was realized as a table, divided into three main categories: *Cause,* for identifying possible causes for the problem described in the case, *Information* for case information and for giving evidence for the causes and *Attribution* for identifying the correct attribution pattern of the cause. The categories *Information* and *Attribution* each contained two subcategories: *Information* was divided in columns for *Consensus* and *Consistency* to make these two aspects of attribution theory salient. *Attribution* was divided into two sections according to the theories of Kelley (1973) and Heider (1958) to help learners attribute each cause to the relevant source.

In the *collaboration script/content scheme* condition (13 Triads), the collaborative unit as well as the shared application was pre-structured. In the *first* phase, learners had to individually complete the content scheme with a paper and pencil. In the *second* phase, the main tasks included the exchange of information and a collaborative collection of all attributions in the shared application. In the *third* phase, learners compared their own notes with the information that had been collected. In the *fourth* phase, learners were asked to develop the solution and to formulate a collaborative case solution in the shared application.

Learners of the *no collaboration script/no content scheme* condition (13 Triads) received no additional support or structure for solving the case collaboratively.

Data Sources

For the analysis, several data sources were included to assess the individual's prior knowledge, the quality of collaborative knowledge construction, and individual learning outcome. A treatment check was also conducted.

An individual's prior knowledge: conceptual knowledge. Conceptual knowledge was measured by a short-answer test for recalling theory concepts. Learners had to complete sentence openers, e.g. "According to Kelley, an event can be attributed to these three causes:". This test consisted of 8 items (M = 26.3; SD = 9.51; empirical max. = 43). The reliability of this test was sufficient (Cronbach's α = .69).

An individual's prior knowledge: applicable knowledge. Concerning an individual's prior applicable knowledge, learners worked on a case individually. For the assessment, this case solution was analyzed with respect to theory concepts and case information. Items used correctly for the individual case solution were summed up as a score (M = 15.0; SD = 6.68; empirical max. = 31). For ensuring inter-rater reliability of data, two evaluators marked analysis 10%. The consistency between these evaluations was high (κ_w = .91).

Quality of collaborative knowledge construction. To assess the quality of the collaborative knowledge construction, the product of the collaborative knowledge construction – a collaboratively solved case – was analyzed with respect to correctly used theory concepts and case information. According to the different categories of the attribution theory, a coding system was developed in which all causes, information and attributions were listed in an identifiable way without any overlap. On basis of this coding scheme, a sum was defined as a measure of the quality of the collaborative knowledge construction. For ensuring inter-rater reliability of data, two evaluators marked analysis 10%. The consistency between these evaluations was high (r = .87).

Individual learning outcomes: conceptual knowledge. Conceptual knowledge in the post-test was measured by a short-answer test for recalling theory concepts. This test consisted of 8 items, which were similar to the items of the pre-test. The reliability of this test was sufficient (Cronbach's α = .62).

Individual learning outcomes: applicable knowledge. For determining individual learning outcome (applicable knowledge), learners solved a case individually after collaboration. Similar to the pretest case, the posttest case was analyzed with respect to correctly used theory concepts and case information. Scores were given for case information and theoretical concepts. For ensuring inter-rater reliability of data, two evaluators marked analysis 10%. The consistency between these evaluations was high (κ_w = .90).

Treatment check. A treatment check was made to ensure that there were no differences regarding learning prerequisites within the four experimental conditions. This served as a control for an individual's prior knowledge and the learner's motivation. Furthermore, the effects of content scheme and collaboration script were controlled regarding the quality of collaborative knowledge construction and the individual learning outcomes.

Data analysis. For verifying the effects of content scheme and collaboration script, a multivariate analysis of variance (MANOVA/GLM) was calculated for the quality of collaborative knowledge construction and the individual learning outcomes. This used the content scheme and collaboration script as factors and an individual's prior knowledge as covariate. Linear regressions were computed to find predictors for the quality of collaborative knowledge construction and individual learning outcome. Non-significant predictors were excluded from analysis.

Table 1: Means and SDs of collaborative knowledge construction and individual learning outcomes.

	Collaborative Knowledge Construction		Individual Learning Outcome (Conceptual Knowledge)		Individual Learning Outcome (Applicable Knowledge)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Total	58.00	*18.73*	29.10	*7.75*	18.58	*6.88*
Max.	92.00		42.00		32.00	
Control	47.18	*14.24*	29.92	*7.41*	15.82	*5.71*
Script	43.00	*11.79*	28.49	*8.40*	15.95	*5.74*
Scheme	66.62	*13.40*	26.50	*9.37*	18.48	*7.77*
Combined	73.46	*15.22*	31.21	*4.40*	22.79	*5.93*

RESULTS

The treatment check disclosed that there were no significant differences regarding prior knowledge and motivation between the four experimental conditions. Furthermore, the effects of the interventions concerning collaborative knowledge construction and learning outcome were calculated including an individual's prior knowledge as covariate. With respect to the quality of collaborative knowledge construction, the content scheme had a large effect. Learners with content scheme clearly applied more concepts than learners without content scheme (cf. table 1; $F_{(1,144)}$ = 127.33; p < .01; η^2 = .47). With respect to individual knowledge acquisition, learners in all conditions benefited greatly during collaboration. The content scheme also proved to be effective for individual learning outcomes with respect to applicable knowledge. Learners with the content scheme scored higher ($F_{(1,144)}$ = 21.84; p < .01; η^2 = .13). With respect to conceptual knowledge, there were no significant differences. Regarding the collaboration script, there were no significant effects regarding the quality of collaborative knowledge construction and the individual learning outcomes. An interaction between the factors of collaboration script and content scheme could not be found, despite the fact that learners with both interventions scored descriptively the highest regarding all outcome measures (cf. table 1).

Research Question 1

Research question 1 was about predictors of the quality of collaborative knowledge construction. As the results in table 2 show, over 45 % of the variance regarding the collaborative knowledge construction could be predicted by prior knowledge and the support measures. The strongest predictor was the content scheme, while the individual's prior knowledge (conceptual) played only a marginal role. The collaboration script and the individual's prior knowledge (applicable) were not significant as predictors. The high amount of predicted variance shows that an individual's prior knowledge as well as the intervention highly influenced collaborative knowledge construction. Unexplained variance may be attributed to other individual learner prerequisites or characteristics of the collaboration process that were not measured in this study.

Table 2: Multiple regression for predicting the quality of collaborative knowledge construction by prior knowledge, content scheme and collaboration script.

	Collaborative knowledge construction (standardized β-weights*)
Prior knowledge (conceptual)	.18
Content scheme	.68
R^2	.49
Adjust. R^2	.48

* Only statistically significant predictors ($p < .05$) are listed

Research Question 2

Regarding predictors for individual learning outcome, the results are quite different (cf. table 3 and 4). With respect to applicable knowledge, 40% of the variance could be predicted by the individual's prior knowledge and collaborative knowledge construction. In the context of applicable knowledge, collaborative knowledge construction exhibited a greater influence than each single measure of an individual's prior knowledge[1]. The content scheme did not prove to be a significant predictor. However, the content scheme may have had an indirect influence, as it is the main predictor for the collaborative knowledge construction. The collaboration script, again, did not prove to be a predictor.

Table 3: Multiple regression for the prediction of individual learning (applicable knowledge) outcome by prior knowledge, content scheme, collaboration script and collaborative knowledge construction.

	Individual learning outcome (applicable knowledge, standardized β-weights*)
Prior knowledge (conceptual)	.27
Prior knowledge (applicable)	.22
Collaborative knowledge construction	.40
R^2	.41
Adjust. R^2	.40

* Only statistically significant predictors ($p < .05$) are listed

When analyzing conceptual knowledge, 60 % of total variance was predictable (cf. table 4). The main predictor was conceptual prior knowledge; applicable prior knowledge played a minor role. Neither the collaborative knowledge construction nor the interventions proved to be significant predictors. However, it must be stated that both tests for conceptual knowledge comprised similar items, even if arranged differently.

[1] When analyzing the effects of collaborative knowledge construction and an individual's prior knowledge (conceptual and applicable) in separate regressions, each of them would be able to predict about 23% of variance. Thus, one could state that the quality of collaborative knowledge construction and an individual's prior knowledge have nearly the same influence on individual learning outcomes with respect to applicable knowledge.

Table 4: Multiple regression for the prediction of individual learning outcome (conceptual knowledge) by prior knowledge, content scheme, collaboration script and collaborative knowledge construction.

	Individual learning outcome (conceptual knowledge, standardized β-weights*)
Prior knowledge (conceptual)	.68
Prior knowledge (applicable)	.16
R^2	.61
Adjust. R^2	.60

* Only statistically significant predictors ($p < .05$) are listed

SUMMARY AND CONCLUSION

These results show that the effects of an individual's prior knowledge are quite varied in the quality of collaborative knowledge construction and individual learning outcome. For collaborative knowledge construction, the influence of an individual's prior knowledge is quite small compared to the influence of support measures. A further outcome is that conceptual knowledge proved to be a significant predictor in contrast to applicable knowledge, which was not a significant predictor. This is an interesting result, considering the fact that collaborative knowledge construction is a task of applying knowledge. Thus, one would expect applicable knowledge to be a predictor. However, considering the content scheme as a strategy for applying knowledge, the presence of this "professional" strategy may have negated the influence of individuals' naïve strategies measured in the pretest. Therefore, the collaborative knowledge construction may have relied in particular on the conceptual knowledge of the individuals and the strategies offered by the support.

The impact of prior knowledge increases when looking at individual learning outcomes. However, in this context, one has to distinguish between applicable and conceptual knowledge. With respect to applicable knowledge, the quality of collaborative knowledge construction still had the most influence. However, looking at the values in table 3, one can assume that the influence of collaborative knowledge construction and both measures of an individual's prior knowledge is somehow balanced[1]. The collaboration did not have an influence on conceptual knowledge. Even if all learners improved their level of conceptual knowledge during collaboration, the main predictor was an individual's prior knowledge. However, this effect may be attributed to the similarity of the test items in the pre- and the post-test.

These results can explain differences between individual and collaborative learning outcomes on the basis of different variables influencing both measures. One can assume that for collaborative knowledge construction, the collaboration effect, including the effect of instructional support measures, is much stronger than individual learners' prerequisites. This means that collaborative knowledge construction can be modified quite fundamentally by instructional support. In contrast, regarding individual learning outcomes, individual prerequisites have a greater influence and may negate the effects of collaborative knowledge construction. This has to be considered when designing instructional support for collaborative learning.

IMPLICATIONS

There are several implications of these findings. First, collaborative knowledge construction can be influenced much more by a well-designed intervention than by an individual's prior knowledge. Secondly, an individual's prior knowledge gains in importance regarding individual learning outcomes, but collaborative knowledge construction still greatly influences this area. These results help explain the effects of many studies which find differences regarding collaborative knowledge construction and individual learning outcomes. However, more research in this context is necessary to be able to generalize these results. Furthermore, the influence of learners with different levels of prior knowledge should be analyzed with respect to group processes and individual learning outcomes.

The educational implications of these findings involve the design of collaborative learning environments. In learning environment research, interventions are often directed either towards achieving a better collaboration process or an improved learning outcome. However, to achieve sustainable learning environments, one has to consider the effect of interventions, the collaborative problem solving process and an individual's prior knowledge. Results of this study show that collaborative knowledge construction can have greater impact than learners' individual prerequisites. This means that carefully designed learning environments may balance out the differences in learners' individual prerequisites. However, such mechanisms must be verified by various process analyses.

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The SENSE Project: A Context-Inclusive Approach to Studying Environmental Science within and Across Schools

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Abstract. This paper describes a project designed to provide children with a context-inclusive approach to collecting scientific data. The term context-inclusive refers to the collection of data which records the process of scientific data collection itself. We outline the design process carried out within two partner schools with the aim of engaging children in taking part in, and reflecting upon, the scientific process involved in collecting and analysing scientific data. We provided children with the ability to share and compare their data with children at their own and other schools. Our context-inclusive approach involved the design of tailored sensors and a bespoke interface displaying video data synchronised with environmental pollution data. Through evaluation of the data collection, analysis and sharing sessions, we describe how the context-inclusive approach impacts on children's understanding of the scientific process. We focus on children's discussion and reflection around understanding the constraints of measuring. We argue that the collection and presentation of contextual data engenders reflection on constraints, and may enable improved understanding of that process.

Keywords. Context, collaboration, eLearning, children, evaluation, sensors, pollution, visualisation

INTRODUCTION

Innovations in Grid computing (Foster et al., 2001) and e-Science will soon enable access to large collections of remote scientific data and high performance visualisations of this data, including data captured from sensor networks, for example as part of environmental science (Steed et al., 2003). The SENSE project, reported on here, builds on such approaches and technologies with the aim of demonstrating how Grid-enabled e-Science sensors might provide data resources for children to collaborate with one another within and across schools.

Several recent projects have involved children collecting data within their local environment and then being connected with other children so that they can make sense of, and compare data (see Cohen, 1997; Lawless and Coppola, 1996; Pea et al., 1997; Tinker and Berenfeld, 1994). As new interactive technologies are developed, new possibilities emerge for children to learn by doing, receive feedback and refine understanding while building new knowledge (see Kafai and Resnick, 1996). Authors have often argued that the nature of investigation is better understood by carrying out one's own inquiry (Dewey, 1910/1964; Resnick, 2000), and many educational institutions aim to help children learn through real world contexts by carrying out field trips and visits. These experiences however, are often peripheral and educational environments have become increasingly structured, allowing limited time for creative participation and autonomy in learning (Resnick et al., 2003; Price et al., 2003).

There is also a move towards using mobile technologies to support class-based experiential and active learning. The RAFT project employed the ideas of mobile learning in remotely accessible field trips (Kravcik et al., 2004). The children on the fieldtrip used tablet PCs, a web cam and microphone to connect to peers back in the classroom who were able to offer extra information to the field group, and input their ideas to the team's goal.

In all this and related work, there is a concern that individual learners gain an understanding of real world context and this can be achieved through exploring and discussing these contexts. Where collaborative learning is concerned, children are often introduced to (aspects of) real world settings to ground their knowledge and understanding. In the SENSE project we have been acutely aware that sensor technologies should be used by teachers and children to aid real world collection and analysis of data. However, while other projects are exploring real world collection of data and the importance of collaboratories involving other children and scientists, we have particularly focused on how the distribution of such data over networks will remove such contextual factors of real-world settings as are afforded by local experience. Accordingly, we have stressed the importance of video to enable children to contextualise the data they are exploring. Children collected data within the natural environment, extending activities that teachers already carried out in class, but giving them additional resources to enhance the relevance of context and engage children further in the process of science such as exposure to time/location methodology.

The contribution of this paper is to inform how the video data collected operates to give contextual cues and therefore understand how best to design remote collaborative technologies. We proceed by describing the sensor technologies and applications we have developed, and then discuss our evaluation of our context-inclusive approach taken from analysis of video recordings of the school data collection, analysis and sharing sessions.

DESIGN ACTIVITIES

Environmental Science in School

The children's domain of scientific work was environmental science, and more specifically pollution monitoring, specifically focusing on carbon monoxide (CO). In order to introduce the domain and use of sensors we developed a programme of activities that spanned one school year. Working closely with the teachers and children at two schools, one in Nottingham and one in Brighton, the aim was to encourage children to think about the process of 'doing science'. The activities were designed to familiarise children with capturing, manipulating and reflecting on their own air quality data, and with using a tailored interface to share data across schools. The children in Nottingham were aged 10-11 years, and in Brighton aged 13-14 years. They generally worked in small groups of 4, accompanied by an adult facilitator when data collecting.

Technologies

In order to conduct these school sessions, we developed a range of technologies that enabled children to input, manipulate and visualise their collected data in a variety of ways. Whilst we are yet to directly integrate with Grid technologies to distribute data across schools, we simulated such an approach by hiding the technical process of data transfer between participating schools.

The small teams of school children were given an array of sensors to measure their local environment: a CO sensor; an anemometer for wind speed; and a video recorder to record the scientific activity in context (Figure 1). In addition, a local map was used to plan measurements locations, and any changes to the plan. The CO sensor equipment was designed for use in environmental scientific research (Steed et al., 2003), and adapted following design sessions in school with the children. CO readings were recorded and displayed by a PDA attached to the CO sensor. The children in Brighton kept the CO sensor and a PDA together on a board, whilst children in Nottingham made the CO sensor multi-coloured and attached it to the end of a stick.

Figure 1. Sensors used to collect environmental data: anemometer, CO sensor with PDA, video recording

Data Analysis Tool

The data analysis challenge for the children was then to manage the different types of data they had and to develop an understanding of what each data type told them individually about their local environment and what the combination of data types offered them in their task of air pollution analysis. For this detailed analysis and reflection task we created a data visualisation tool for use in the classroom. Our tool displayed a graph of the CO data, along with time-synchronised video data recorded by the children (Figure 2). Annotations of interesting and surprising points recorded by the children were then added to the graph, e.g. when a large vehicle passing did not appear to increase the CO reading. Annotations were displayed as a red point on the graph.

ANALYSING AND SHARING

Our analysis focuses on the children's understanding of the scientific process, particularly how understanding the constraints of CO measurement is impacted by the provision of contextual data alongside measurement data. We examine how children explored measurements whilst considering methodological issues in data collection. We focus on critical incidences around factors such as delayed readings, effect of the wind on the readings, and recall on incidences of particular import. We divide our analysis into the particular stages of the process from data collection, through analysis and finally through reflection on data provided by the other school.

Data Collection

Hypothesising about expected CO readings began in the classroom during route planning activities. The nature of obtaining immediate readings whilst out collecting data meant that these hypotheses could be discussed, and location decisions altered during the data recording session to develop more in-depth hypotheses about how CO behaves, and the properties of the sensing devices in use. In one example, a group of children saw a lorry coming out of their school and waited to measure exhaust fumes as it passed. No change was recorded by the sensor, with the reaction "that's rubbish!" elicited from one in the group. Using knowledge about the equipment, the group decided to alter the position of their sensor at a roadside location and place it on the pavement, closer to traffic exhaust fumes. They further hypothesised that their position by a pedestrian crossing would reveal higher readings because "at the traffic lights cars stop then they start again so they must… chuck a lot more carbon monoxide out." A lower reading than expected was gained here and the children reflected on the equipment they were using, and also whether wind may be responsible for that reading.

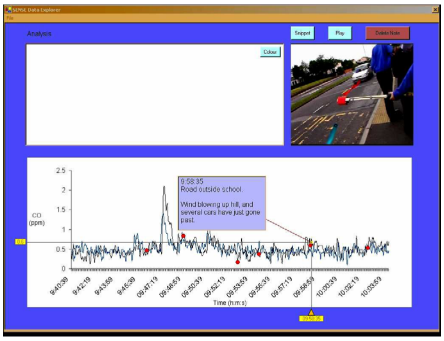

Figure 2. Data Analysis Tool Interface with CO graph, annotations and video context

Data Analysis

On the following day, the children used the data analysis tool to inspect their data. The group mentioned above developed their own ideas about how their equipment worked. At the time of the lorry incident it was not apparent that their monitor had detected an increase in CO. One girl noted, "The lorry didn't do much [to our CO reading]… we would have thought there would be more pollution, it's a big vehicle and we were standing right behind it".

Reviewing the video data, another child then noticed, "It suddenly goes up in a minute… What happened at 10:09? The next bit where we stopped it goes up really high". Another responded, "It might be we haven't actually got the carbon monoxide yet, it's sort of floated… and then it started reading". They then chose to annotate their graph with their hypothesis about the equipment, "We expected more of a change in carbon monoxide [by lorry] it took longer than we expected about 30 secs or maybe a minute to go up slightly".

The sensor used in Nottingham was attached to the end of a long stick. This enabled children to experiment with holding it in different positions in relation to the traffic. The wind ribbon was also attached to this stick underneath the sensor. The children recorded the wind direction in relation to the hole on the sensor where the air enters. These two factors led children to experiment with trying to 'catch' pollution, by turning the sensor to either face the wind, or to face the direction they believed the car exhaust would be coming. These brief instances highlight the children's awareness of how the design of the sensing technology could influence the results.

The facility to view synchronised video and CO data was used both as a memory aid for what was done, and as a way for absent children to participate in the later reflection stages even though they had not witnessed data collection first-hand. Our intention for data annotations was that they would enable others to access the reflected thoughts of the children who captured the data, whilst providing further opportunity to add in their interpretation of the data or hypotheses. Comments that were inserted included location-relevant information, wind observations, notes about malfunctioning equipment, reasons for location choice and reasons for different sensor positions and orientations.

In the classroom we discussed reasons for high readings which did not seem to connect to any occurrence of heavy traffic. Children talked about how the wind could disperse or focus CO. One interesting feature of our use of video was that the video camera also acted as an indicator of particularly windy conditions due to the noise from the camera's microphone as wind blew across it. Children also talked about how air enters the sensor via a hole in the sensor casing. The directional nature of the hole, together with the wind, can affect the reading of CO. In this respect the design limitations of the technology enabled the children to gain a deeper understanding of CO and air movement. It also made them critical about the results they obtained, realizing that there are not always direct mappings between readings and pollution. Interpretation was needed in order to begin to make sense of what was happening, and contextual cues taken from annotations and video data were relied on in these instances.

Sharing and Reflection

To engage the school children further in understanding air pollution and promote deeper reflection on their findings, children had the opportunity to ask questions of children at the other school who had engaged in the same project. These data sharing sessions occurred between remote others who were not known before the session. Prior to communication, children from each location were given the opportunity to review the other location's video, CO and annotation data using the familiar analysis tool. Discussions centred on noticing differences in data collection methods, e.g. the two schools used different methods of collecting wind data (a ribbon versus an anemometer), how the sensor was mounted (a stick versus a board), and the different types of annotations made. Comments were made about the sensor design "theirs is on a stick"; about the scale of CO data, "they've got over 200 [parts per million CO]!"; and "What does wind towards mean, and wind across?", referring to annotations.

The feedback obtained from the participants in the session provided understanding of alternative ways to carry out a study. It opened up dialogue on aspects that children at each location had so far taken for granted:

"We held ours [CO sensor] lower to the ground and got a lower reading but they held theirs higher up and got a higher reading so if we were to do it again I would probably hold it up in the air not put it down"

Most notably, the kinds of reflection which occurred relied most prominently on the contextual data, such as annotations and video views of data collection, in understanding how the measurements were differently structured and obtained.

DISCUSSION

Gordin and Pea (1995) suggest that the ability of the human mind to quickly process and remember visual information suggests that concrete graphics and other visual representations can help people learn. We certainly believe that the video of the context in which the children took their readings aided children in understanding and reflecting upon the data they had collected. They also helped children make sense of the conditions and context in which the data sets from the other school were collected and enabled them to reflect on the method as well as the results. We believe this context-inclusive approach is significant for three reasons. Firstly, it allows individuals to reflect on method as part of data collection. Secondly it provides an aide-memoir to groups who have collected data together in interpreting results. Thirdly, it allows new participants who have engaged in similar processes to understand new perspectives on their own and others' data. It is not difficult to imagine the import of such findings for activities required by national curricula in situations where schools are networked together. Our initial studies have shown that contextual data can allow the remote participation of schools at a distance with plausible outcomes of comparison and reflection on both process and results. Such a process does not just support locally-directed learning, indeed it relies on the differences in local interpretations of scientific activities. Such interpretations are then bridged by children at remote sites through the use of contextual data.

We have identified important specific features of our approach. Firstly, the use of a common interface in presenting and analysing data is beneficial in later cross-school interpretation. Secondly, contextual data may include a number of features. In the case of SENSE, we have used time-synchronised video data and time-indexed freeform textual annotations. Finally, we highlight a range of future possibilities for furthering our approach.

Initially, we have noted possibilities for further contextual data. For example, the impact of wind on our particular scenario of pollution indicates that visualisations of wind data might prove useful. More generally, it is the case that trails on a map displaying GPS data would also provide interesting contextual cues (e.g., see Iacucci et al., 2004).

Future direction would involve designs that take into consideration the methodological issues that children were reflecting upon. For example:

- By developing software which calculates or averages time differences between reading points and annotation points, so that understanding time delays in registering readings can be considered.
- By using unanticipated features of the contextual data, such as wind noise over the video camera microphone to consider the contextual properties of each of our data sources.

In discussions, Tom (year 9) reflected "Going outside to actually measure it yourself, makes you really think about what you are doing and not just reading it out of a book cos then it doesn't mean much". As such, and following Tom, the experience retained much of the child-directed approaches to learning that research in CSCL has repeatedly shown to be an important feature of learning. Nonetheless, by encouraging children to collect what we have termed context-inclusive data, we have facilitated an integration of individual, small group and remote collaboration. The use of contextual data has supported consideration of methodology across all three whilst allowing children to collaborate across schools without the financial and time costs of field trips and long-term programmes.

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No Need to Read Messages Right Now: Helping Mediators to Steer Educational Forums Using Statistical and Visual Information

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Abstract. In an education environment, a forum provides a valuable tool that can be used to foster reflection and a deeper analysis of subjects being discussed. However, as an asynchronous communication tool, participation can occur at any time, demanding a constant attention of the teacher to satisfactorily mediate the group and the discussion. In addition, a reasonable number of messages can be posted in a short period of time, making it hard to follow up and coordinate the discussion. This paper proposes an approach based on statistical and visual analysis of messages characteristics to alert the teacher about potential problems.

Keywords: Forum, Coordination, Message Inspection, Collaboration

INTRODUCTION

Working in groups brings some characteristics, such as synergy, ability to consider more information, objective evaluation, cognitive stimulation, contribution of different understanding and exposure to alternative points of view, that can enhance learning [Benbunan-Fich & Hiltz, 1999][Hiltz, 1994]. Group members can monitor individual thinking and group structure provides social support and encouragement for individual effort. By formulating ideas in their words and receiving evaluation from peers, students' knowledge, thinking skills and meanings are socially constructed [Harasim et al, 1997]. Moreover, working with peers tends to reduce anxiety as learners share solutions to complex tasks, increasing satisfaction with the process and results.

In asynchronous collaboration events, learners can participate at a time and a place convenient to themselves and appropriate to the task, having more time to reflect before composing their contributions. In addition, besides the fact that extrovert personalities continue to contribute more than quieter members do, they cannot dominate completely as in synchronous or face-to-face situations. Quieter members still have the opportunity to contribute [Straus, 1996]. Others learners that may feel that they do not have enough time to prepare their thoughts in a fast-paced discussion also have in the asynchronous events a better opportunity to expose their ideas and to contribute to the discussion in a slower-paced, less time-limited way [Funaro & Montell, 1999]. The asynchronous format also allows students to work through difficult texts and concepts more slowly, and to help each other to understand the contents [Bull et al, 2001].

A forum is an asynchronous textual communication tool that can be used to create threaded discussions, where the relations between a message and the one that it is responding to is visually characterized. As students' responses are posted publicly and become persistent in the environment, they tend to contribute more thoughtfully, working their arguments and backing up their ideas with evidence before turning them into essays [LaGrandeur, 1996]. They can also share their thinking with each other, comment on each other's ideas and find partners that share their interests in order to get in a deeper discussion [Funaro & Montel, 1999]. In this networked learning, students should be aware that they are much more responsible for their success, looking for their own sources of information and learning how to deal with information overload and how to convert collaboratively information into knowledge, turning them into learners who actively generate knowledge rather than being passive receivers [Harasim et al, 1997].

However, in order to be successful, a forum demands a close attention of the mediator, mainly in the initial sessions when participants are not used to the adopted dynamic yet. The mediator must mediate the forum in order to guarantee that learners participate properly, that the discussion does not drift to a nonproductive direction and that the flow of information is neither too monotonous nor unmanageable [Salmon, 2000]. In addition, by reducing the pressure to respond, it is easier for a student to drop out of the group [Graham et al, 1999]. The mediator has to demand regular contributions in an appropriate timeframe to avoid dispersion.

Most environments do not provide a desirable specific computational support, leaving to the mediator all the effort to collect and analyze the information necessary to mediate group discussion. As the contributions may occur at any time and at any rate, it gets really hard to the mediator to constantly monitor, read and follow up the discussion in order to intervene before noise propagation.

This paper proposes the use of a statistical and visual analysis that can be offered by the environment, allowing the mediator to timely intervene in the discussion, by saving him from the immediate need of inspecting each message. In order to mediate the discussion, the mediator must communicate, coordinate and cooperate [Fuks, Gerosa & Lucena, 2002]. This paper focuses on the coordination aspect of the collaboration. Coordination is the additional effort needed to organize the group in a manner that channels communication and cooperation towards the group's objective [Raposo & Fuks, 2002]. When coordinating a forum group discussion, the mediator must ensure that each learner participates, that the contributions add value to the discussion and that the conversation does not drift to nonproductive direction.

In this paper, this analysis is restricted to a set of message characteristics that can be extracted without the need of human inspection, namely message chaining, category, size and date. Measurements such as the average depth level of the discussion tree indicates the depth of the discussion that is taking place, and the percentage of leafs do the same for the level of interaction. Message categorization provides a way to focus the analysis on the specific message type in need of attention. Message size helps to identify messages that are not consistent with others of the same type. By analyzing message timestamp, it is possible to identify the time range between messages and their rate. Cross referencing this data also reveals other information, such as the type of message expected per level, how fast the tree grows, which types of messages are answered more quickly etc.

For the case study, data were extracted from a regular online course of the Computer Science Department of the Catholic University of Rio de Janeiro. This course, which currently is in its 14th edition, runs in the AulaNet learning management system. The course and the system are briefly presented in the next section.

THE COLLABORATION SCENARIO

In order to collaborate, members of a group should communicate, coordinate themselves and cooperate. While communicating, they negotiate and make decisions. While coordinating, they deal with conflicts and organize the group in a manner that avoids the loss of communication and cooperation efforts. While cooperating, they work together in a shared space, seeking to complete tasks, generating and manipulating cooperation objects. Renegotiation and decision making regarding unexpected situations turn up while cooperating, thus, demanding new rounds of communication, which on its turn, will require more coordination to reorganize the tasks to be further executed during the next round of cooperation. This cycle shows the iterative nature of collaboration. Participants interact, obtaining feedback from their actions and feedthrough from the actions of their companions by means of awareness elements. The diagram shown in Figure 1 summarizes this cycle. It is based on models found in the literature, such as the 3C model proposed by Ellis et al. [1991] and the Clover design model [Laurillau & Nigay, 2002]. This paper focus is on the coordination aspect of collaboration.

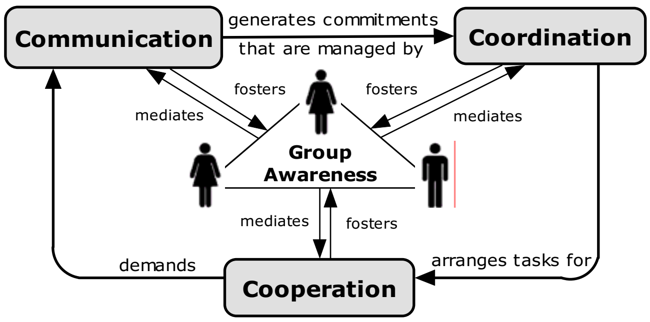


Figure 1. Overview of the 3C collaboration model.

The AulaNet learning management system provides an environment for teaching and learning via Web and was developed based on the 3C collaboration model. It has been under development since June 1997 by the Software Engineering Lab of the Catholic University of Rio de Janeiro (PUC-Rio). The AulaNet is a freeware and it is available in Portuguese, English and Spanish versions[1]. During 2002, 2003 and 2004, more than 6000 university students and 20000 workers in their companies have been using AulaNet.

The Information Technology Applied to Education (ITAE) course has been taught entirely at a distance using the AulaNet environment since 1998. Its objective is to get learners to collaborate using information technology, becoming Web-based educators [Fuks, Gerosa & Lucena, 2002]. The course seeks to build a

[1] AulaNet: http://groupware.les.inf.puc-rio.br or http://www.eduweb.com.br

learning network where the group learns, mainly, through the interaction of its participants in collaborative learning activities.

Some points of the course's dynamics need to be characterized for the sake of the case study. The course is organized by topics, with one topic being discussed per week. Learners read selected content regarding the weekly topic, conduct research to enhance their understanding about it and, then, take part in an asynchronous discussion about three specific questions regarding that topic. This discussion is carried out over 50 hours using the AulaNet Conferences service, which implements a forum. To close the weekly discussion, learners revisit the same questions using a chat tool during one hour.

In the ITAE course, the role of transmitting information and leading the discussion, which generally is an attribute of course mediators, is shared with learners. A learner is selected in each conference to play the role of the *seminar leader*, being responsible for preparing an initial message followed by three aforementioned questions, referred by group members to develop their argumentation. During this phase, the seminar leader is also responsible for keeping the discussion going on and maintaining the conference's dynamics.

In AulaNet, the learner can select a category for the message from a set that have been previously defined by the course teacher [Gerosa, Fuks & Lucena, 2001]. The available categories in the ITAE course, used to identify the message type, are *Seminar*, *Question*, *Argumentation*, *Counter-Argumentation* and *Clarification*. In the ITAE course, the seminar leader posts a message from the *Seminar* category to serve as the root of the discussion, as well as three messages from the *Question* category. During the following 50 hours, all learners engage in the discussion.

Each Conference message is graded and commented upon individually by the mediators in order to provide guidance to learners on how to prepare their texts, avoiding the sending in of contributions that do not add value to the group. Contributions are commented upon in the message itself, generally in a form that is visible to all participants, so that the learners better understand where they can improve and what they have gotten right.

ANALYSIS OF MESSAGE CHARACTERISTICS

Analyses about message chaining, categorization, size and date are presented in this section, illustrating how these characteristics can help in the coordination of educational forums. The data and examples were collected from seven editions of the ITAE course (from the second semester of 2001 to the second semester of 2004).

Message Chaining

Communication tools have different ways of structuring messages: linear (list), hierarchical (tree) or network (graph), as can be seen in Figure 2. Despite the fact that a list is a specific case of a tree, and this is a particular type of graph, no one structure is better than another. Linear structuring is appropriate for communication in which the chronological order of the messages, such as the sending of notices, reports and news, is important. Hierarchical structuring on a forum, on the other hand, is appropriate when the relationships between messages, such as questions and answers, need to be quickly identified. However, it is relevant to point out that, since there is no way to link messages from two different branches, the tree can only grow wide and, thus, the discussion takes place in diverging lines [Stahl, 2001]. Network structuring can be used to seek convergence of the discussion.

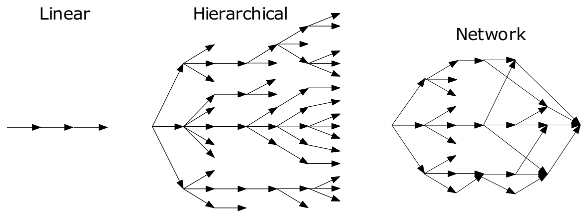


Figure 2. Examples of discussion structure

In the ITAE course, the forum, based on the AulaNet Conferences service, is used for the in-depth discussion of the course's subject matter. The format of the resulting tree indicates the depth of the discussion and the level of interaction [Pimentel, Fuks & Lucena, 2003]. For example, a tree like the one exemplified in Figure 3 has only three levels, which indicates that there was almost no interaction, given that level zero is the seminar message, level one comprises the three questions and level two comprises the answers to the questions. This means that learners only answered the initial questions.

Figure 3. Example of a corresponding tree

The trees extracted from the conferences of the five editions of the ITAE course are shown in Figure 4. It can be also noted that in some editions the depth of the tree become shallower over the semester while in others it becomes deeper. It can be seen that in 2003.1 and 2003.2 the trees gets deeper, indicating that learners improved their argumentation skills during those semesters. On the other hand, in 2002.1 the trees got shallower over the semester, most probably due to lack of coordination. It is also possible to observe that normally the first conference corresponding tree is the shallowest one. It is possible for example to visually compare the depth of the conferences of a given edition with those of other editions. However, in order to conduct a more precise analysis, it is also necessary to have statistical information about these trees, as presented in Figure 5.

The trees shown in Figure 4 and the charts in Figure 5 indicate that the interaction on the 2002.1 edition declined over the course of the conferences, while the interaction on ITAE 2003.1 edition increased. It can be seen in Figure 5 that the average depth of the trees in the 2002.1 edition declined while the percentage of messages without answers (leafs) increased, which indicates that learners were interacting less as the course progressed. In the first four conferences of this edition, the average level of the tree was 3.0 and the percentage of messages without answers was 51%; in the last four conferences, the average tree level was 2.8 and the leafs were 61%. On the other hand, in the 2003.1 edition, learners' interaction increased over the course: the trees were getting deeper while the leafs were decreasing. The average depth level was 2.2 in the first four conferences, increasing to 3.0 in the last four, while the percentage of leafs went from 69% in the first four conferences to 53% in the last four. While the 2002.1 edition learners slowly decreased their interaction level, the 2003.1 edition learners quickly increased their interaction level. Another indication of the declining interaction level of the former is the continuous decline in the number of messages.

All this information was obtained without having to read messages. Comparing the discussion trees during the progress of the course should be enough to let mediators intervene in order to guarantee a maximum depth level, a minimum number of leafs and a desirable amount of messages. Mediators may also intervene when a given conference is not following an expected quantity of messages per level. This pattern is shown in Figure 6.

In level 0, where just a seminar message is expected, there is an average of one message in each tree of the course editions. In level 1, there is an average of 3 messages, which are the three questions proposed by the seminar leader. Level 2 contains the arguments responding direct to a question, forming a peak in the quantity of messages. In level 3 and thereafter the number of message decreases. If the quantity of messages in a given level of a tree in a given conference departs significantly from this pattern, mediators should intervene.

Message Categorization

Upon preparing a message, the author chooses the category that is most appropriate to the content being developed, providing a semantic aspect to the relationship between messages. Looking at the categories, learners and mediators estimate how the discussion is progressing and the probable content of the messages. The AulaNet does not force the adoption of a fixed set of categories. The teacher who plans the course can change the category set to the objectives and characteristics of the group and their tasks.

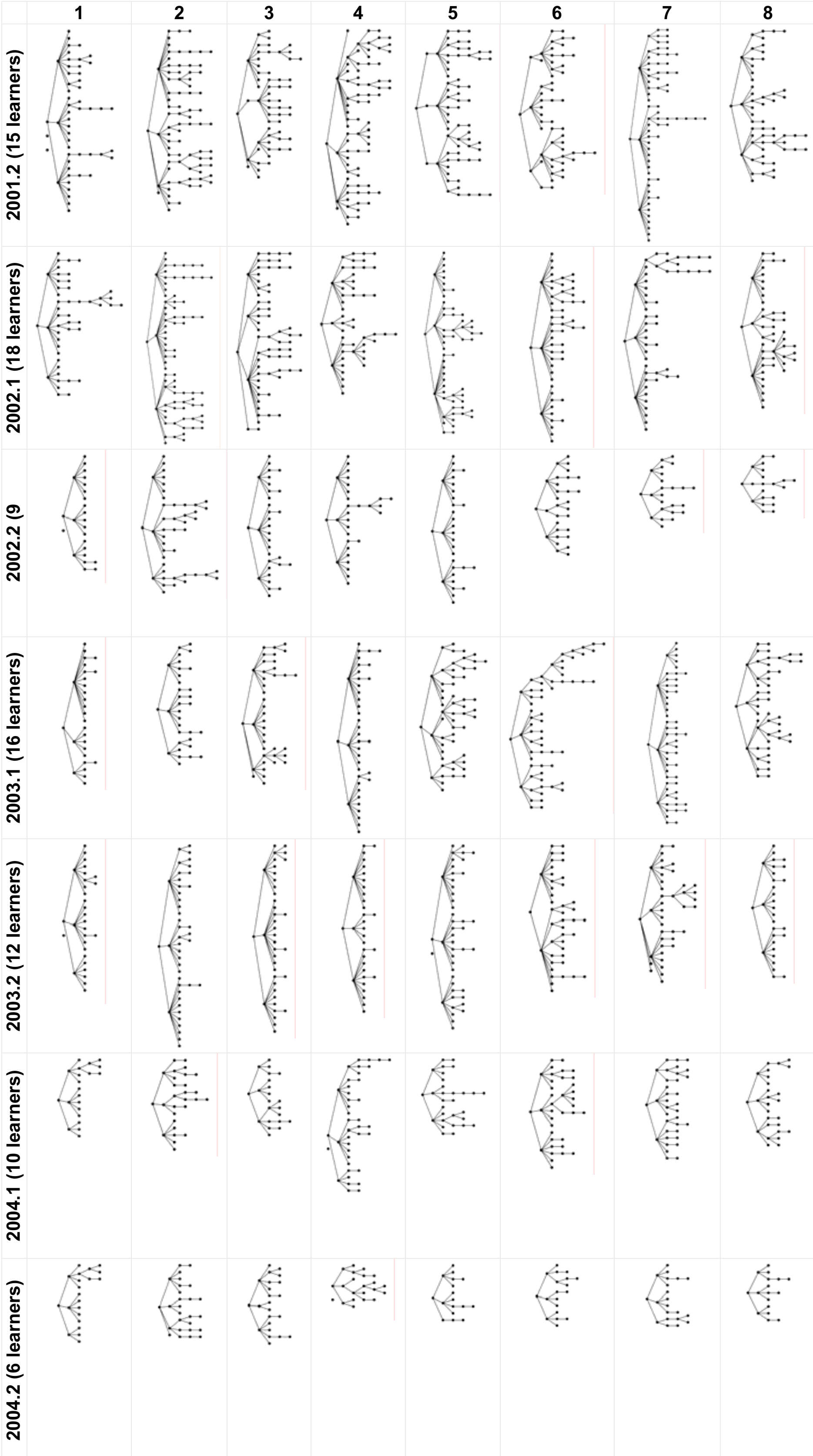


Figure 4. Trees extracted from the eight weekly conferences of the five editions of the ITAE course

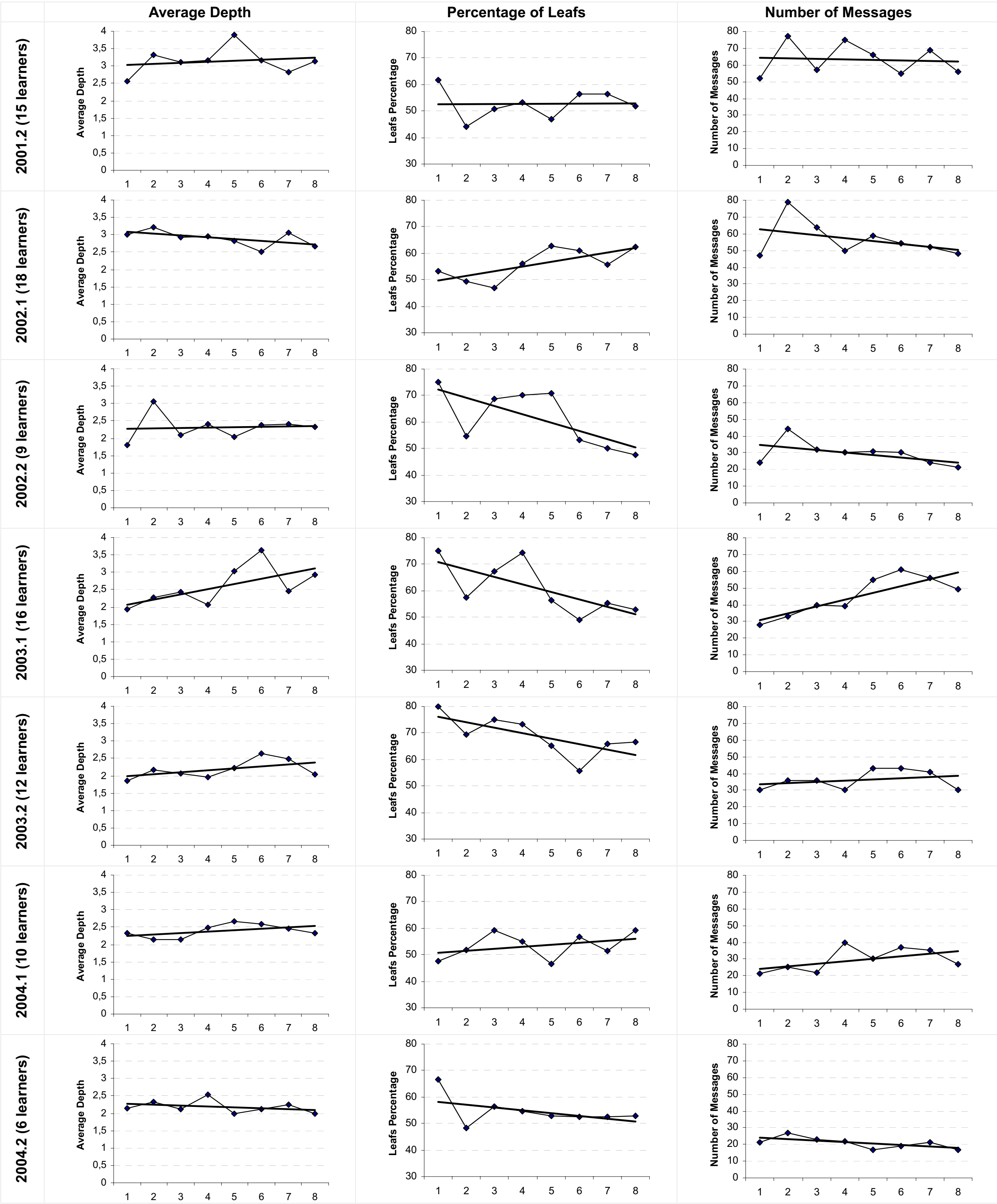


Figure 5. Average depth, leafs percentage and number of messages of each conference of the course editions

The categories adopted in the ITAE conferences were originally based on the IBIS' node types [Conklin, 1988]. The categories adaptation was made based on the information provided by follow-up reports furnished by AulaNet, like category usage per participant [Fuks, Gerosa & Lucena, 2002]. Currently, the categories defined in the course are: *Seminar*, for the root message of the discussion, posted by the seminar leader at the beginning of the week; *Question*, to propose discussion topics, also posted by the seminar leader; *Argumentation*, to answer the questions, posing the author's point of view in the message subject line and the arguments for it in the body of the message; *Counter-Argumentation*, to be used when the author states a position that is contrary to an argument; and finally, *Clarification*, to request or clarify doubts about a specific message.

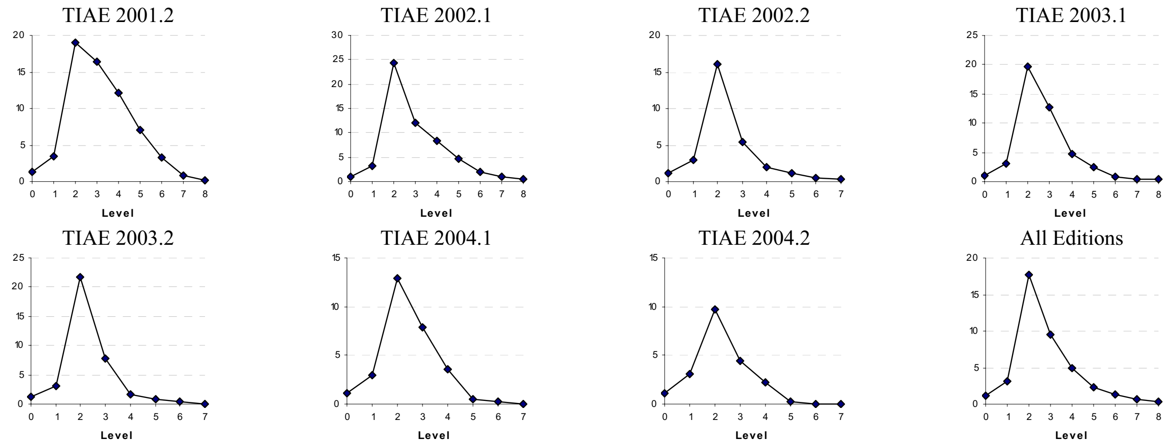


Figure 6. Average quantity of messages per tree level corresponding to the conferences

Figure 7 presents the percentage of messages of each category on the different tree levels of the course. As expected, one can observe that on level 0 (the tree root), the predominant category is *Seminar*, on level 1 it is *Question*, and on level 2 it is *Argumentation*. The *Counter-Argumentation* category begins to appear on level 3 and its relative usage increases; the use of the *Clarification* category begins to appear as of level 1 (it is possible to clarify a seminar or a question). Those messages whose relationship between the category and the level differ from what has been described, normally, derive from choosing a wrong category.

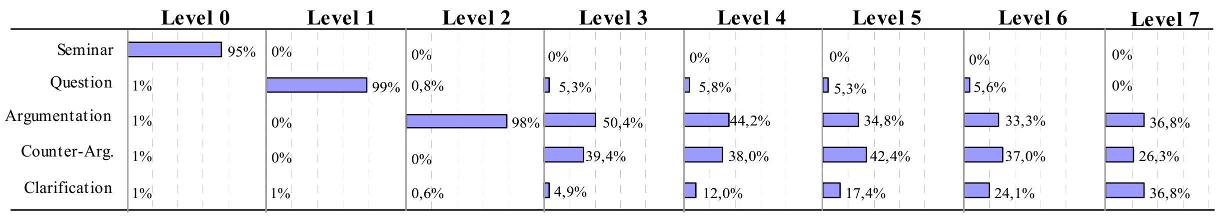


Figure 7. Percentage of utilization of the categories per tree level

The category also helps to identify the direction that the discussion is taking. For example, in a tree or a branch that only contains argumentation messages, there is no idea confrontation taking place, which is bad for the argumentation practice. Similarly, excessive counter-argumentation should attract mediators' attention. The group might have got into a deadlock or, even worst, there may be interpersonal conflicts taking place.

Message Size

As each category has a different semantics and influences the way that messages are composed, message size analysis was made for each category. Figure 8 presents the average values of characters for each category and average deviations. In this figure, one can see that the *Seminar* category is the one having the largest messages, followed by *Argumentation* and *Counter-Argumentation*. The shortest messages are those belonging to the *Question* and *Clarification* categories.

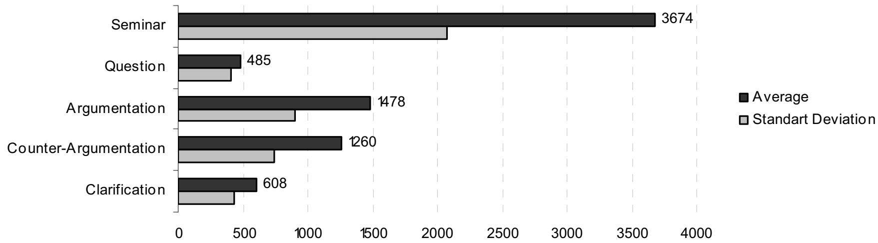
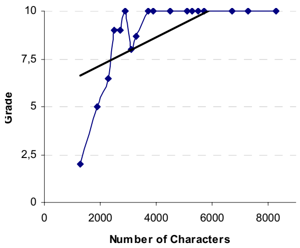


Figure 8. Quantity of characters per category

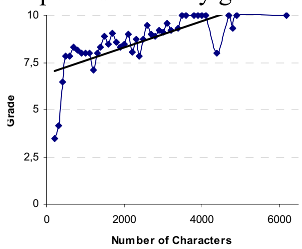
During an edition of the course, one of the learners said: "When we counter-argue we can be more succinct, since the subject matter is already known to all." If the subject is known to all (because it was presented during the previous messages) the author can go directly to the point that interests him or her. This can be noted in the chart in Figure 9, which shows a decline in the average quantity of characters per level in the *Argumentation* (correlation coefficient = -86%) and the *Counter-Argumentation* (correlation coefficient = -92%) categories. The analysis was restricted to these two categories because *Seminar* and *Question* do not show in higher levels and *Clarification* seems to be level independent regarding size (correlation coefficient = 48%).

Figure 9. Quantity of characters in the messages per level of the argumentation (on the left) and counter-argumentation (on the right)

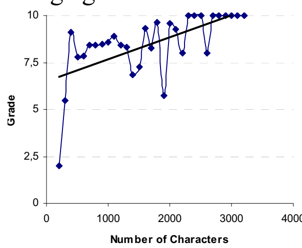
The expected amount of characters for a given message helps mediators identify problematic situation. Figure 10 presents a chart showing the amount of characters versus the average grade of the messages in the *Seminar*, *Argumentation* and *Counter-Argumentation* categories. It can be the seen that messages having an amount of characters much lower than the expected normally get a lower than average grade.



a) Seminar



b) Argumentation



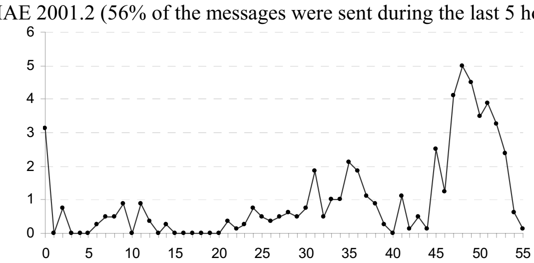
c) Counter-Argumentation

Figure 10. Amount of characters versus grade per category

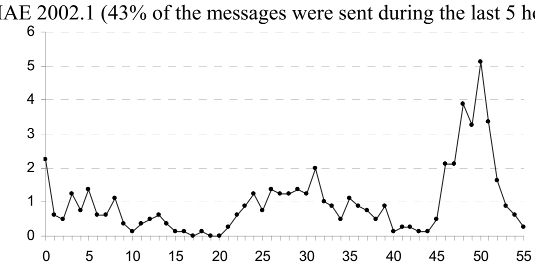
Message Date

On the ITAE course, the conference goes for 50 hours: from 12 noon Monday to 2 pm Wednesday. Figure 11 presents the hourly rate of messages sent during conferences. Until the 2003.2 edition, it can be seen that there is a burst during the last five hours of the conference. In some cases, more than 50% of the messages are sent during this period of time. This phenomenon of students waiting until the last possible moment to carry out their tasks is well known and has been dubbed “Student Syndrome” [Goldratt, 1997]. The act of sending contributions near to the deadline disturbs an in-depth discussion, given that last-minute messages will neither be graded nor be answered during the discussion. This might be the reason for an excessive amount of leafs on the trees in some conferences, hence, less interaction.

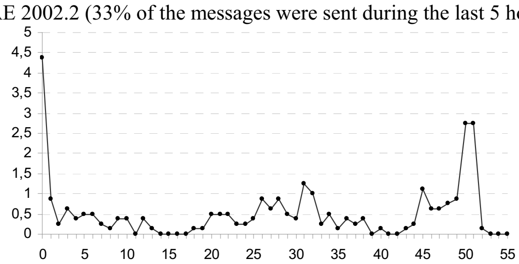
TIAE 2001.2 (56% of the messages were sent during the last 5 hours)



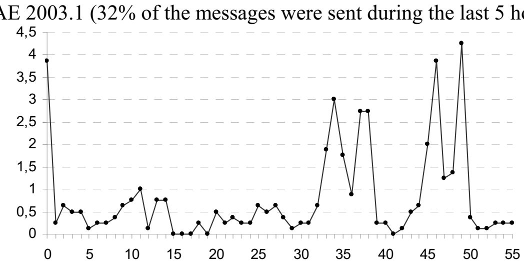
TIAE 2002.1 (43% of the messages were sent during the last 5 hours)



TIAE 2002.2 (33% of the messages were sent during the last 5 hours)



TIAE 2003.1 (32% of the messages were sent during the last 5 hours)



TIAE 2003.2 (45% of the messages were sent during the last 5 hours)

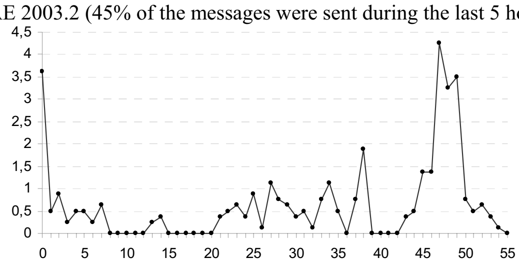
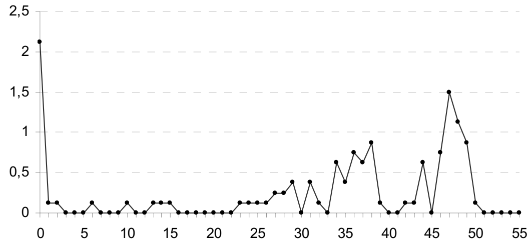


Figure 11. Average hourly rate of messages of the 8 conferences from 2001.2 until 2003.2 edition

In order to avoid this unwelcome behavior mediators have to encourage the earlier sending in of contributions. Unfortunately, our experience with this course has shown that this encouragement does not work. In the 2004.1 edition, the following experiment was conducted. The last 4 conferences had a different assessment rule than the first 4 conferences: if until the 25th hour the learner had not sent half of the expected amount of messages, the grade of all the messages sent during the following 25 hours would be divided by 2. The new rule seemed to work.

First 4 conferences (33% messages sent during the last 5 hours)



Last 4 conferences (13% messages sent during the last 5 hours)

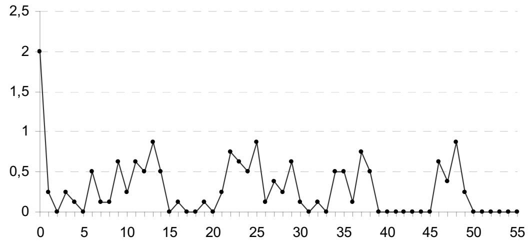


Figure 12. Average hourly rate of messages of the 4 first and 4 last conferences of the 2004.1 edition

In Figure 12, the second chart does not show message burst indicating that the rule has worked. The percentage of messages sent during the last 5 hours of conference felt from 33% in the first half of the course to 13% in the second half. Nevertheless, there are lower 25th and 50th peaks. However, now mediators and learners have room to access and answer the first batch of messages. The same thing can be seen in Figure 13, where all 8 conferences of the 2004.2 edition were assessed based on the aforementioned rule. In this conference, an average of 18% of messages was sent during the last 5 hours.

TIAE 2004.2 (18% of the messages were sent during the last 5 hours)

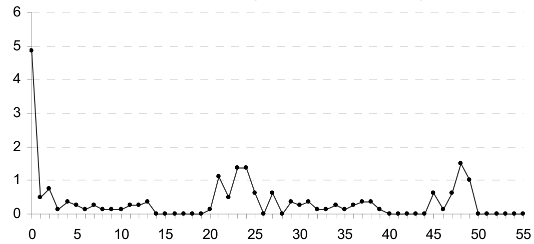


Figure 13. Average hourly rate of messages of the 8 conferences of the 2004.2 edition

For the moment, the no-need-to-read-messages-right-now measurements stop there. From this point on, mediators have a clear picture of what is going on in the conferences, but there is no way of avoiding the reading of messages. Anyhow, the conferences seem to be more balanced as an effect of the steering done by the mediators based on the use of statistical and visual information.

CONCLUSION

Communication among learners takes a fundamental role in the learning process through the exchange of information and points of view and interconnecting the group. Groupware technology supports collaborative learning activities, providing an environment where group interaction takes place. A forum provides a valuable tool that can be used to foster reflection in a paced learning. However, educational environments still do not offer computational aids that are appropriate for coordinating forums.

Message chaining, categorization, size and message timestamp are characteristics that help in the coordination of educational forums within ITAE. Based upon the form established by message chaining, it is possible to infer the level of interaction among course participants. Message categorization provides semantics to the way messages are interconnected, helping to identify the accomplishment of tasks, incorrect message nesting and the direction that the discussion is taking. The analysis of message timestamp makes it possible to identify the Student Syndrome phenomenon, which gets in the way of the development of an in-depth discussion.

By analyzing the characteristics of messages, mediators are able to better coordinate learners, having indication of when to intervene in order to keep the discussion from moving in an unwanted direction. Furthermore, these analyses could be used to develop filter for intelligent coordination and mechanisms for error reduction. It should be emphasized that these quantitative analyses provide indications and alerts about problematic situations, but also show whether the discussion is going well.

A well coordinated forum does not necessarily imply in learning taking place, it is still up to the teacher to insert forum-based relevant activities in the course dynamics and to motivate learners to ensure learning outcomes. The statistics and analysis presented in this paper help to better mediate the discussion process and to identify uncommon situations, which does not necessarily means problems; it requires the teacher to check them out, inspecting the content of the discussion. In addition, although this paper is focused on the teacher mediation, the information presented may also be used by learners to better coordination themselves.

There is no ideal visual and statistical outcome that educators should steer their course towards. The teacher should interpret the statistical and visual information taking into consideration the course's and participants' characteristics. Final decision and judgment are still up to mediators. Discourse structure and message categorization also help to organize the recording of the dialogue, facilitating its subsequent recovery. Based upon the tree form, with the help of the categories, it is possible to obtain visual information about the structure of the discussion [Kirschner et al, 2003]. Mediators using collaborative learning environments to carry out their activities should take these characteristics into account for the better coordination of educational forums.

ACKNOWLEDGEMENT

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The Role of Floor Control and of Ontology in Argumentative Activities with Discussion-Based Tools

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Abstract.

Abstract. Argumentative activity has been found beneficial for knowledge building and evaluation of information in some conditions. Many CSCL theorists have suggested that graphical representations may help in this endeavor. In the present study we examine effects of a graphical representation of synchronous discussions. 54 Grade 7 students from 2 classes participated. The study tested the effects of: (a) the use of shapes representing some argumentative functions in discussions and the use of arrows representing support/challenge between utterances; (b) the use of floor control to monitor turn taking during discussion. It appears that the combination of use of shapes and arrows and of the control over turn taking invites students to express more relevant claims and arguments, and less chat expressions.

Keywords: Argumentation, Knowledge Building, (a)synchronous e-discussions

Bell (1997) has recognized two types among representations of argumentation. The first type, *knowledge representation tools*, supports the construction of argumentation whose structure and content correspond to a valid argument. Examples of such environments are SenseMaker (Bell, 1997) and Belvedere (Suthers & Weiner, 1995). The ontology of the representations generally displays viewpoints, reasons, and data or backing separately according to a Toulminian terminology of argumentation. Suthers (2002) notes that environments such as Belvedere provide representational guidance, that is a set of *constraints* and *saliences* (or *affordances*) that initiate the negotiation of meaning. As noted by Schwarz and colleagues (2003), the categories proposed in the ontology of the representation also scaffold argumentative activity: the ontology is used intuitively in informal discussions, but when it is represented, it leads discussants to be more explicit about the argumentative functions of their interventions

The second type, *discussion-based tools,* consists of graphical representations of argumentative moves of participants in discussions, that is, of argumentative processes. As such, displays are personalized. The CSILE environment (Scardamalia & Bereiter, 1994) is a well-known discussion-based tool, whose representations are extremely simple. When discussing an issue, students are required to enter notes with identified types of content: “My Theory”, “I need to understand”, Comment”. Each CSCL argumentative environment is designed to enable a new discussion space, new ways of negotiating and co-constructing meanings. As in the case for knowledge representation tools, choices must be made concerning the ontologies available, the ways to communicate among participants (the modalities), tools available to evaluate, or the role of the teacher.

van Bruggen, Kirshner and Jochem (2002) showed that the decisions taken by designers about types and functions enabled are theory-driven, but admitted that experimental data have no impact on the re-design of the environments. They also admitted that no real research has been done to check the effects of characteristics of argumentative environments on the construction of knowledge. In the present paper, we study how children use a discussion-based tool to construct arguments. We examine the effects of several conditions of use on construction of arguments. The present study is a part of a design research effort initiated by a pedagogical concern to create an environment for fostering collaborative learning through argumentation (Schwarz & Glassner, 2003). The overall plan in the elaboration of the environment is to provide tools to be used in different domains such as history or science. We decided to use elaborate a discussion-based tool for maintaining personal engagement: Discussion-based tools display the identity of discussants in all interventions as well as their addressees. Knowledge construction is then the product of a social activity in which participants attempt to strengthen their standpoints, to weaken the standpoints of others, or to co-elaborate an agreed argument. In a recent study (Schwarz & Glassner, in press), we designed a first version of the DUNES environment whose central component was a discussion-based tool. With this alpha version, we enabled a-synchronous discussions. Small groups of junior high-school students discussed ethical issues. Two types of settings were formed: discussants that used the same shapes for all their interventions, and discussants that used differentiated shapes for different argumentative moves (undifferentiated vs. differentiated ontology). We showed that providing differentiated ontology of argumentative moves helped constructing arguments, which were deeper (with more chains of inference), broader (with more perspectives), and socially denser (with more references to peers previous interventions). This first study led us to redesign the DUNES system and to considerably refine coarsely enunciated research questions.

In the design of the beta version of the DUNES system (see later on), we aimed at enabling full-fledged synchronous discussions. We differentiated two types of synchrony: participating in the same e-discussion on-line (a) without floor control (each participant enters his/her intervention whenever he/she wishes so) and (b) with floor control (a round of turns is posted; it corresponds to the time order of requests for interventions). The present study considerably refines the results obtained in the first (pilot) study and checks the working hypotheses that stemmed from it as usual in design research. It investigates effects of synchrony (with and without floor-control) and of ontology in e-discussions mediated by graphical representations. We present now the beta version of the DUNES environment, whose design stemmed from the first study.

DESCRIPTION OF THE DUNES ENVIRONMENT

The DUNES environment is a CSCL argumentation representation (discussion based) tool. In order to motivate students to engage in discussions, we followed the advice of several researchers (van Bruggen & Kirschner, 2003; Schwarz & Glassner, 2003) to propose students 'cases' (also called 'ill-structured' or 'wicked problems') that is, problems for which (a) there is no unique expected answer, (b) the ways to progress to an acceptable solution are varied and (c) participants have some informal knowledge. To do so, we often used a narrative from daily life. We hypothesized that such characteristics trigger students' engagement in argumentative activities. We asked teachers to initiate cases through a verbal introduction or through the DUNES Oasis, a web portal for the preparation of materials. The Dunes Oasis is intended to be used as a platform for initiating a-synchronous or synchronous (with or without floor control) communication with application sharing, voting, chat, and other communication services, launching a client-based graphic discussion map, and setting and editing learning materials for all users.

The script of a case contains definitions for the schedule, pedagogical goals, content-related goals, etc. An example of content-related goal is to differentiate between the role of primary and secondary texts in the elaboration of interpretations in history issues. The pedagogical goals are generally non content-related goals that teachers expect the users to learn. Examples are learning how to negotiate, or how to argue, about how to reach a better understanding of how we trust (or do not do so) what somebody is telling us, etc. The pedagogical goals are very often implicit for the users. In the design of a case, instructors decide on the social settings of activities such as the size of groups of discussants (small groups of 2 to 6, whole group forum, or individuals). We now turn to the representation of discussions in the DUNES environment realized in the Digalo web tool.

Digalo (http://zeno8.ais.fraunhofer.de/digalo/index.html) is a central component of the DUNES system (www.tessera.gr/dunes/index). It enables the management of discussions and the representation of their argumentative processes and components among participants. Using Digalo consists of co-creating maps (see Fig. 1) built of written notes inside different shapes, and different arrows representing different connections between the shapes. Shapes may have attachments and links to external web resources and connections to the library. Every map has an ontology that specifies and constrains not only the admissible labels for the shapes (such as opinion, fact, reason, defending, challenging), but also the different 'roles' to be played when manipulating the map. The choice of ontology is intended to create a discussion space that constrains how the discussion can develop. When using Digalo the facilitator of the discussion (generally the teacher or the designer but in some cases a student) presents a blank map, and decides on the ontology to be used in e-discussions. The modes of communication in Digalo may be verbal or electronic in synchronous or a-synchronous discussions. Verbal and electronic modes of communication may concur when students are in the same computer room. The electronic mode of communication may include the synchronous use of the Pad with a chat channel. The synchronous use of the Pad (with which the present experiment has been undertaken) can be done with or without 'Floor Control' (FC): When FC is activated, only one person can work on the board (add shapes and edit text in shapes). The first to request FC receives it immediately while others

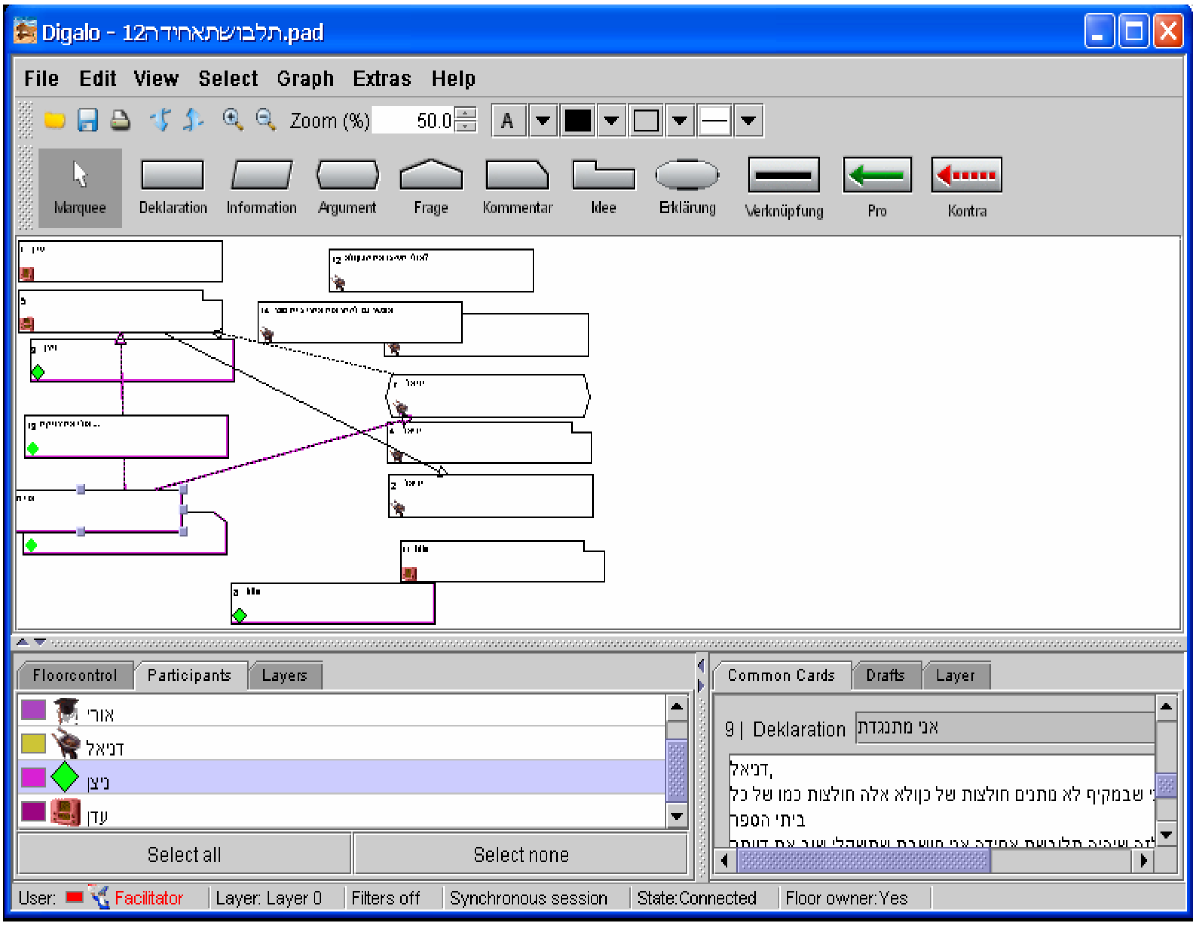

Figure 1. A Digalo map (the map of Nitsan's group)

will enter a line for receiving FC. As soon as the student finishes writing his/her contribution, s/he releases FC and by doing so, allows other students who requested FC, to add contributions. The facilitator can decide whether one student will receive FC before others or can take FC from a student if s/he thinks this is necessary. When FC is deactivated, all participants can work simultaneously, without taking turns. In each of the contributions, participants add one shape (or more) and arrows/links to the shapes built by others to articulate own claims, arguments, questions, etc. Each participant chooses a distinctive color and an icon that help identifying his/her contributions on the board. Figure 1 shows the on-going construction of a map with Digalo.

DESCRIPTION OF THE RESEARCH

We focused on two aspects of Digalo, the role of ontology and the role of floor-control in turn taking during synchronous e-discussions. The general research question was to what extent floor control in turn taking and argumentative ontology are beneficial to the construction of arguments relevant to the issue at stake in the discussion. The term "beneficial" points both to better arguments-products and to more topic-centered discussions. We hypothesized that the combination of the use of rich ontology (different shapes for several argumentative moves) and the control of turn taking would yield the most argumentative discussions: participants were expected to write more relevant claims and arguments and less chat expressions than participants in the other groups. Our hypothesis on the beneficial effect of rich ontology was based on the first study. We hypothesized that no floor control would lead to more chat-style writing. Our hypothesis was not based on empirical findings since no such research has been done so far on e-discussion maps. Our definition of chat-style writing was not well articulated.

Population.

54 Grade 7 students from two classes participated in the study. The students were knowledgeable about common computer applications (internet, data-bases, Office tools). The teachers organized students in 12 discussion groups. Each group included 3 to 6 students. The groups were heterogeneous according to their verbal ability.

Independent variables.

The first independent variable was the ontology, differentiated and non-differentiated. The differentiated ontology included the following argumentative components: "claim", "information", "explanation", "question", and "other". Such ontology fits a context in which students did not learn about argumentative moves but rather use intuitive, informal discursive skills. The components were embodied in different shapes. In addition, two sorts of arrows were available, arrows that expressed a support and arrows that expressed opposition. In the case of non-differentiated ontology, students had boxes at disposal, all of them with the same shape, in which they entered text for each of their interventions. The second independent variable concerned the activation or the non-activation of floor-control (FC) in Digalo. For the FC option, the order of turns was automatically determined by the time requests were done. According to the two independent variables, the 12 groups operated in the following conditions: (i) for 3 groups, the ontology was undifferentiated and there was no FC (G1); (ii) For 3 groups, the ontology was undifferentiated with FC (G2); (iii) For 3 groups, the ontology was differentiated and there was no FC (G3); (iv) For 3 groups, the ontology was differentiated with FC (G4).

Dependent variables.

The dependent variables were: (a) the number of relevant claims (conclusions, opinions, viewpoints concerning the controversial issue), (b) the number of relevant arguments (i.e. reasoned claims; claims with information or explanation that support them), (c) the number of chat-style expressions, (d) the number of superficial references to other participants, and (e) the number of productive references to other participants. When counting the relevant clams and arguments, we did not refer to the shapes used but to the utterances themselves, since we did not test whether the shapes used matched their intended function in discussions.

Procedure

Each of the 12 discussion groups underwent two different sessions in the same computer laboratory. Each group was instructed to discuss the controversial issue "whether or not wearing school uniforms at school is binding", by using Digalo. At the time of the experiment, this issue was an actual dilemma and the principal board was interested to know about the students' views. The experimenter and the teachers prepared in advance the different discussion

settings (i.e. inserted the names of the participants, and defined the representation shapes and arrows and the turns option for each group setting).
In the first session, at a first stage, each student was invited to write on a paper his/her personal viewpoint on school uniforms and to give as many reasons as possible that support his/her viewpoint. Each student was then invited to figure out the opinion of somebody with a different viewpoint, and to give reasons supporting this viewpoint. The second stage of the first session was devoted to familiarization with Digalo. Then, each participant in his/her group was invited to write a personal story with the boxes in Digalo by inserting one idea/event/remark in each box.
In the second session, at a first stage, all participants were instructed to engage in Digalo discussion about the uniform issue. They were asked first to present their personal opinions. Then, they were instructed to continue the discussion and were enabled to react to each other. The time for discussion was limited to twenty minutes.

Collection of data and analysis.

The data we collected were the Digalo maps produced during discussions. We did not take into consideration whether discussants chose the right ontology for each intervention (claim, argument, other, or information). Students were not instructed about this ontology except for a short demonstration of the experimenter; we were interested to observe which kind of e-discussion the ontology could afford, taking into consideration that students have an intuitive sense of the proposed ontology. A general caveat concerning the coding procedure: Although it is always possible to combine different interventions to a complete argument, we counted as arguments only interventions in which the discussant linked explicitly a claim and a supporting element (in one box or by using an arrow). The coding was validated by an inter-rater procedure in which three experts first evaluated five maps and negotiated disagreement. One expert coded the remainder of the maps.
Our primary aim was to study relevant claims and arguments as dependent variables that are indicators of argumentative talk. The more discussants express claims and arguments relevant to the issue at stake, the more they are engaged in argumentative talk. Since students experienced synchronous mapped e-discussions for the first time, we also adopted a qualitative grounded method for the collection of data enabling an open approach for the definition of categories and variables after a first overview of all the maps. For example, we discovered after the collection of data different kinds of informal expressions such as pet names, curses, or chat-like turns. Students did not use such terms in their previous experience with DUNES in a-synchronous e-discussions. Such expressions fit students experience with common chat tools.
Another variable that stemmed from a first analysis of the data was the quality of the reaction to other discussants. We asked whether the reaction was productive (by providing details or explanations on the issue at stake) or not.

Unit of analysis

The unit of analysis of the maps is the written content of each intervention. It includes the title and the adjunct comment. The comment is visible as a window when one participant double-clicks on the box or as a bubble when one puts the pointer on the box. Otherwise, the maps display titles only.

Coding of the variables

For each intervention, we asked the following questions: does the intervention include (a) a claim relevant to the issue at stake; (b) a relevant argument; (c) a chat expression; (d) a reference to others' interventions; a superficial or a productive reference. For each of the discussants we counted the number of relevant claims, relevant arguments, chat expressions, references to others and productive references.

Coding the number of relevant claims

We considered as relevant claims any utterance that expressed an idea: opinions, perspectives, conclusions, etc. relevant to the issue. Examples of claims: “Listen, there’s no need for uniforms”, “I’m against uniforms”, “I don’t have any opinion on the topic, yes or not to wear a uniform”.

Coding the number of relevant arguments

We considered as relevant arguments (groups of) utterances including a viewpoint and reasons relevant to the issue. Examples of relevant arguments are: “I’m against because uniforms are boring, and in my opinion, everybody must be free to choose what to wear”, “I’m both pro and con because some children offend others with what they wear and because everybody must look special”, “I’m for it because it’s fun that everybody looks the same, and because we choose our cloths quickly”.

Coding of chat style expressions

We sorted chat expressions according to three categories: use of nicknames, curses, and turns from Internet culture. Examples of use of nicknames are: “Ori, the great look”, “The Artist #17”, “Helen the sexiest, listen to her”. An example of (mild!) curse is: “Reaction to Nisim’s sister”. Examples of Internet turns are: “response to Ohad 1”, “reaction to Noga reaction to me”.

Coding references to other participants

References were coded as superficial or productive. Examples of superficial references are: “In my opinion, you bother only about yourself” or “You’re not right, you’re turncoats”. Examples of productive references are: “Ohad, Amir, even if uniforms are boring, they can’t cause you not to recognize your friends” or “Noga. I think that you’re 100% right. I read in the newspaper on a school that decided on uniforms and the students didn’t wear uniforms in the same plain way but tore and cut uniforms”.

RESULTS

We undertook the analysis of the results in two stages. In a first stage we ran an ANOVA test to find main effects and interactions between ontology and floor control in relation to the dependent variables. Then we ran LSD post hoc tests in order to isolate the effect of independent variables. Table 1 displays averages and standard deviations of the dependent variables for the four experimental groups, as well as the result of the ANOVA test for the four variables (the average number of claims, arguments and chat expressions from each group – these numbers were globally computed in each group, then were divided by the number of the students in each group)

Table 1 shows clear effects of ontology. G3 and G4 (who used differentiated ontology) expressed more relevant claims than G1 and G2 who used undifferentiated boxes ($F(1, 50) = 5.69$), $p < .05$). As for the number of relevant arguments, the results were not found significant although the same tendency persisted. The effect of ontology was also found for the number of chat expressions. The number of chat expressions among G1 and G2 was found higher than among G3 and G4 ($F(1, 50) = 6.99$; $p < .05$). Concerning the effect of floor control, the number of superficial references to other participants’ utterances, was found higher in groups that discussed the issue without floor control ($F(1, 50) = 8.03$; $p < .001$). Also the number of chat expressions was found higher among students without floor control ($F(1, 50) = 9.02$; $p < .001$). In order to locate the origin of the effects, we undertook LSD post hoc tests. Concerning the chat variable, differences were found between G1 and G2 and between G1 and G3 ($p = .005$) and of course between G1 and G4 ($p = .000$). In other words discussions without floor control and without arrows and differentiated ontology invite students to adopt a chat style. A comparison between G1 and G4 with regard to the number of relevant claims ($p = .038$) suggests that the high number of claims stems from the combination of floor control and differentiated ontology with arrows. As for the number of relevant arguments, since although ANOVA did not uncover effects, the same tendency persisted, we undertook a post hoc test. We found an effect between G1 and G4 ($p = .045$) as well as between G2 and G4 ($p = .023$). Since both in G2 and G4 the discussion was with floor control but in G2 students did not use differentiated ontology and arrows, we can conclude that the effect concerns the use of ontology and arrows only. As for superficial references, the differences between G1 and G4 ($p = .019$) and between G3 and G4 ($p = .045$) show that in discussions without floor control and with differentiated ontology, there were more superficial references than when differentiated ontology and floor control were combined. In the next section we illustrate the findings by presenting two examples of discussion that contrast G1 and G4, the most different experimental groups.

Table 1. The results of the four experimental groups

	G1 (N=16) Onto. no/ FC no	G2 (N=14) Onto. no/ FC yes	G3 (N=13) Onto. yes/ FC no	G4 (N=11) Onto. yes/ FC yes	Ontology effect F(1, 50)	FC effect F(1, 50)	Interaction F(1, 50)
Relevant claims	2.06 (1.44)	2.36 (2.37)	3.31 (2.10)	3.72 (2.05)	5.69*	0.43	0.01
Relevant arguments	1.50 (1.32)	1.29 (0.73)	1.62 (2.14)	2.72 (1.68)	3.46	1.15	2.51
Productive references	0.56 (1.15)	0.57 (0.85)	0.85 (1.52)	1.18 (1.25)	1.82	0.27	0.24
Superficial references	1.19 (1.47)	0.43 (0.65)	1.08 (1.19)	0.18 (0.40)	0.38	8.03**	0.05
Chat-style expressions	2.44 (1.63)	0.79 (1.12)	0.92 (1.75)	0.27 (0.65)	6.99*	9.02**	1.70

*p<.005; **p<.001

TWO EXAMPLES OF E-DISCUSSIONS

We follow in the first example a group of four discussants in G4 (with differentiated ontology and with floor control. Figure 1 (presented above) displays part of the discussion map produced by the group. The example will help clarifying problems about the coding procedure. Nitsan's interventions are labeled with a lozenge sign. Nitsan, a female student, intervened three times in the discussion in addition to her first intervention in which she expresses her personal viewpoint on uniforms in schools. We list here all Nitsan's interventions as scripts including the shape chosen, the title, the comment and the arrow(s) the discussant drew. These scripts can be tracked in Figure 1.
In the first stage, discussants are asked about their opinion; they do not express reasoned claims naturally:

Utterance #3: Creator: Nitsan; Ontological type: Claim; Title: Nitsan; Comment: I'm neither pro nor con although I wrote on the worksheet that I'm pro, I change my mind to the middle, yes as well as no; Link with arrow to: _____

At this stage Here only one relevant claim could be identified.
We turn now to the second stage of the use of the Digalo, the e-discussion:

Utterance #6; Creator: Nitsan; Ontological type chosen: Other; Title: Nitsan
Comment: Dear Eden… I don't think that we should revoke uniform cloths right away. There's some negative side but if after all there are uniform clothes, one shouldn't be upset but one should see the positive side. You shouldn't revoke the proposition of uniforms right away! Nitsan.
Link with arrow to: Eden's utterance #5 (opposition)

We counted one relevant claim, *I don't think that we should revoke uniform cloths right away*, and the reason invoked, *one should see the positive side.* We also counted one reference to Eden materialized by an arrow of opposition to utterance #5.

Utterance #8; Creator: Nitsan; Ontological type chosen: claim; Title: I'm against
Comment: Daniel, I think you're wrong because in high school they don't supply KENVELO shirts. They supply the same shirts in all schools and if this is the reason you agree for uniform I think you have to reconsider your opinion.

Link with arrow to: Daniel's utterance #7 (opposition)

There is one claim (*you have to reconsider your opinion*), one argument, and one productive reference to Daniel.

Utterance #12; Creator: Nitsan; Ontological type chosen: claim; Title: Maybe you're right
Comment: Daniel, there is something in yours ideas but try to imagine that you buy a new shirt and you desire to show it to everybody and because of the uniform, you can't do it. Depressing, right? I'm not against uniform and I'm not pro because there are advantages because it's fun and you don't need to choose clothes in the morning and children who have money will not be ashamed with their clothes. But as I said before, there are drawbacks, as I said, you buy a new shirt and you cannot wear it and you really wish everybody to see it…it's depressing…or you wish to show the new clothes…you see everything has drawbacks and advantages. If there will be uniform you should look at the good side of it, and if not, you also have to see the good side.
Link with arrow to: ________

The first claim we identified is *Maybe you're right* and an argument that supports it. The second claim is: *Everything has drawbacks and advantages* and its argument. The utterance includes a productive reference to Daniel. If we summarize Nitsan's utterances Nitsan expressed five claims, and four arguments. All references to Eden and Daniel are productive since they lead to the elaboration of new arguments. Nitsan's interventions did not include any chat style expression.

We describe now the interventions of a male student named Yair who belonged to G1 (without floor control and with undifferentiated ontology). We present here Yair's interventions only, without the interventions of his peers. Yair intervened five times in the discussion in addition to the personal viewpoint he expressed before the discussion. We list here these six interventions:

1. *Title: "Amazing Yair's box. Worth reading". Comment: "I strongly oppose wearing uniform because many children don't want uniform since they have a lot of other cloths and in my opinion it's impossible to decide for people what to wear"*
2. *Title: "I strongly oppose wearing uniforms because there are a lot of children who are against uniform and they have a lot of different clothes and to my opinion you can decide for other people what to wear"*
3. *Title: "To Helen". Comment: "What? Uniforms? Don't be maniac! [Russian curse] Go home and wear a uniform!*
4. *Title: "To Shiran". Comment: "Great explanation"*
5. *Title: "To Shira Meir". Comment: "Great explanation and I'm sorry people laughed at you. It was not on purpose!"*
6. *Title: "To Shira Meir". Comment: "What a chutzpah. Why you don't answer, witch"*

Contrarily to Nitsan's interventions that developed as the discussion progressed, Yair's interventions turn shorter and shorter. In his first personal intervention, Yair writes a claim ("I strongly oppose wearing uniform") and explanations for this claim ("they have a lot of other cloths" and "it's impossible to decide for people what to wear"). From the first contribution to the discussion onward, Yair's interventions are short, replete with chat style expressions ranging from nicknames ("Amazing Yair") to curses. References to peers' interventions are superficial ("great explanation", "Why don't you answer"). In spite of a quite articulated first intervention to the e-discussion, Yair's contribution to the whole discussion consists of one argument and one claim only.

DISCUSSION

Even for their very first encounter with Digalo, students could elaborate ideas during their e-discussions in certain conditions: the combination between the use of argumentative ontology and the floor control for turn taking afforded the expression of more relevant claims and arguments and of less chat expressions. Ontology was the main factor leading to these effects. The use of shapes and arrows then affords focused discussion on the issue at stake. These quantitative findings fit some qualitative findings concerning the ontology effects found in the first study (Schwarz & Glassner, in press). It seems that the constraint to think about the role of each utterance and its relation to other utterances before, during and after this Digalo utterance leads to a meta-discussion effect and subsequently to deeper and more meaningful discussions about the discussed topic. The FC may give the opportunity – by the time one must prepare oneself and must read others' utterances before one's turn, and to think about the role of one's utterance according to the ontology chosen. More generally, the findings suggest the high potential in the use of Digalo to lead to productive talk, in the sense that construction of knowledge and understanding are fostered. These are only suggestions, though: In the present study we could not test whether individual arguments actually improved as a result of the e-discussions. Students were over-tired to rewrite their personal view on the same issue after they did it twice before (on paper and within the discussion). Also, the issue at stake concerns a quite narrow range of objects for discussion, dilemmas about daily-life issues rather than scientific knowledge (in a Vygotskian sense). A vast program of research on the use of Digalo, and on the use of discussion based tools for the acquisition of scientific knowledge is still an unexplored domain. Baker (2003) began pioneering research in that direction, but with knowledge representation tools. He showed the necessity of 'heavy' tutoring with such representational tools in order to acquire scientific (physical) knowledge. While we hypothesize that the acquisition of scientific knowledge with discussion-based tool should also necessitate a kind of monitoring, we suggest that the help provided should be based on less directives, and should be different in nature.

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ACT: A Web-Based Adaptive Communication Tool

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Abstract. This paper presents a web-based adaptive communication tool, called ACT. ACT supports and guides the learners' communication/collaboration by implementing the structured dialogue either through sentence openers or communication acts. The scaffolding sentence templates are adapted according to the cognitive skills addressed by the learning activity, the model of collaboration followed and the educational tool used. The learners have the possibility to personalize the communication/ collaboration process by enriching the provided set of the scaffolding sentence templates with the desired ones and to monitor their debate in a visual graphical representation form through the Dialogue Tree. The first empirical results are encouraging regarding the predetermined set of the scaffolding sentence templates and their proper use, the adaptation framework supported, the provided facilities and the coherence of the dialogue.

Keywords: Communication, structured dialogue, sentence openers, communication acts, scaffolding sentence templates, adaptation, Dialogue Tree

INTRODUCTION

Peer interaction is acknowledged as a significant factor in collaborative learning. However, the learners do not necessarily have the desired productive collaboration/communication skills (e.g. provide explanations, ask questions, engage in argumentative discussions) (Lazonder, Wilhelm & Ootes, 2003; Soller, 2001). Structuring approaches aim to create appropriate conditions by designing and scripting the collaboration framework before the interaction begins (Andriessen, Baker & Suthers, 2003). In this context, the structuring of the dialogue is used as an approach to encourage and guide learners to certain types of communication (Andriessen, Baker & Suthers, 2003). The structured dialogue may follow a fully or semi-structured form implemented through sentence openers or communications acts, enabling learners to compose their message and denote their underlying intention by using predetermined *Scaffolding Sentence Templates* (SST).

Results from various research efforts indicate that the use of the structured dialogue supports and increases learners' task-oriented behavior, leads to more coherence in discussing argumentatively the subject matter, promotes reflective interaction, lightens the learners' typing load, guides the sequence and the content of the dialogue, enables the monitoring and the interpretation of the ongoing discussion and is characterized as an adequate pedagogical approach for virtual learning groups (Baker & Lund, 1997; Soller, Lesgold, Linton & Goodwin, 1999; Hron, Hesse, Cress & Giovis, 2000). However, the potential improper use of the SST and the restriction of the learners' choice of words imposed by the structured dialogue are two disadvantages to be taken into account during the development of synchronous communication tools (Lazonder, Wilhelm & Ootes, 2003). According to Lazonder et al. (2003), the SST should be derived from naturally occurring online text-based free dialogues while Soller (2001) states that it is important to provide the widest and most appropriate range of SST.

A number of synchronous communication tools have been developed (either integrated in a CSCL environment or as standalone tools) to support the dialogue through a structured communication interface. In BetterBlether (Robertson, Good & Pain, 1998), the communication interface consists of sentence openers, which support the skills of good communication, trust, leadership and creative conflict. The communication tool of the LeCS environment (Rosatelli & Self, 2002) provides a set of sentence openers, which facilitates the process of reaching an agreement, while specific expressions enable learners to express their emotional state. The communication tool of the EPSILON environment enables learners to communicate through sentence openers which are classified to categories according to the Collaborative Learning Conversation Skills Taxonomy (Soller, 2004). ALEX (Hirsch, Saeedi, Cornillon & Litosseliti, 2004) is a structured dialogue tool, which enables learners to make arguments by selecting and completing partial sentences (sentence openers) and facilitating learners to make references to already sent messages. Jermann and Schneider (1997) in their tool called

Conference MOO, support both the free-text and the structured dialogue; the structured dialogue is implemented through four buttons (e.g. "I don't understand") and four sentence openers (e.g. "I propose"). They assert that the learners' preference on a specific dialogue mode (free or structured) depends on the particular content type (i.e. task, strategy and interaction management). Also, the Co-Lab tool (Lazonder, Wilhelm & Ootes, 2003) supports the free-text and the structured dialogue. All these tools support the implementation of the structured dialogue through sentence openers and provide a fixed set of SST regardless of the context of the collaborative activity and the collaboration framework followed. Moreover, they provide limited degree of personalization (i.e. few tools enable learners to select between the structured and the free form of the dialogue).

Our research efforts take previous work in structuring the dialogue in synchronous communication tools one step further, by attempting to:

(i) implement the structured dialogue either through sentence openers or communication acts depending on the learning outcomes (i.e. cognitive skills) addressed by the collaborative activity and the model of collaboration followed by the group members,
(ii) provide the most meaningful and complete set of SST adapted according to the collaboration framework followed in the collaborative activity (i.e. the cognitive skills addressed by the collaborative learning activity, the model of collaboration followed and the educational tool used), and
(iii) offer learners the possibility to personalize the communication/collaboration process by enriching the provided set of the SST with the desired ones.

To this end, we developed a synchronous communication tool with adaptive capabilities called ACT (Adaptive Communication Tool). The learners can monitor the dialogue progress and reflect on their communication/collaboration by accessing the Dialogue Tree as well as the results of the quantitative analysis of their debate at any time during the elaboration of the activity. The first results revealed from the formative evaluation of the ACT tool are encouraging regarding the predetermined set of the SST and their proper use, the adaptation framework, the provided facilities (the monitoring of the dialogue through the Dialogue Tree and the enrichment of the SST) and the coherence of the dialogue. Moreover, they drew useful implications concerning the way the SST are provided to learners as well as the adaptive and adaptable capabilities of the ACT tool.

The rest of the paper is structured as follows. In the following section, we present in detail the functionality of the ACT tool in terms of the SST provided, the adaptive capabilities supported, and the facilities provided to the learner. Afterwards, we discuss the results from a study that we conducted in the context of the formative evaluation of the ACT tool. The paper ends with the main points of our work and our near future plans.

THE ACT TOOL

ACT was developed in the context of a web-based adaptive collaborative learning environment, referred to as SCALE (Supporting Collaboration and Adaptation in a Learning Environment) (Grigoriadou, Gogoulou, Gouli & Samarakou, 2004). The SCALE environment follows the conceptual framework of the Activity Theory (Engeström, 1987; Cole & Engeström, 1993) and supports (a) *the individualized learning*: enables learners to work on learning activities, provides personalized feedback and guides/supports learners during the elaboration of the activity through pedagogical agents, (b) *the collaborative learning*: enables learners to work on collaborative learning activities, supports the group formation of the learners based on their individualized characteristics and the characteristics of the activities, supports alternative models of collaboration between the group members, promotes and facilitates the synchronous communication between the group members, and guides the learners at the communication and at the learning level through pedagogical agents, and (c) *the assessment process*: supports the automatic assessment of the activities, the collaborative assessment and the peer assessment and provides feedback tailored to learners individual characteristics and needs.

The ACT tool can run as a standalone communication tool or in the context of the SCALE environment, supporting the synchronous communication of the learners in groups of up to four persons. The learners communicate in the context of a specific collaborative activity which addresses cognitive skills that are classified to one of the four levels: *Comprehension level* (Remember + Understand), *Application level* (Apply), *Checking-Critiquing level* (Evaluate) and *Creation level* (Analyze + Create) (Gogoulou, Gouli, Grigoriadou & Samarakou, 2004). Moreover, a specific model of collaboration is followed during the elaboration of the activity; the group members may collaborate either having the same duties or undertaking different roles. In any case, one of the group members plays the role of the moderator, being responsible for the coordination of the group process (e.g. proceed to the next question, terminate the communication session), the summarization of the debate and the submission of the final answer.

The ACT tool aims to guide and support the learners appropriately during their debate. To this end, we followed the structured form of the dialogue aiming to (i) eliminate the off-task discussions, (ii) guide the learners towards the underlying learning outcomes of the activity or the duties and responsibilities implied by the model of collaboration, and (iii) enable the automatic interpretation of the learners' interaction as well as the tracing of the dialogue states. The functionality of the ACT tool in terms of the SST and the facilities provided to the learner as well as the adaptivity of the tool are discussed in the following.

Using ACT

The ACT tool enables learners to communicate and collaborate in the context of a learning activity. The learners have to fill, in the corresponding log in form, their username, the activity index and the sub-activity index. Once all the group members are logged in, the tool enters into the communication mode otherwise the tool enters into the wait mode, showing which members of the group are already connected. Figure 1 presents the main screen of the ACT tool as it appears at the communication mode. It consists of the following areas:

- The *Dialogue Area*, which shows the debate that has taken place. The messages are recorded, numbered and presented in a chronologically sent order. Each dialogue message has the form: [message_number] [sender]: [message composed by the sender].
- The *Message Composition Area*, which enables the learner to construct the desired message on the basis of the SST provided (an analytical description of the message composition process is given in the section entitled "Communicating with ACT").
- The *Message Submission Area*, which enables the learner to submit the message to all or to selected members of the group.

Upon the completion of the collaboration in the context of the activity, the learners may proceed to the elaboration of another subactivity (they can select the desired one through the option "Session/Change Subactivity") or terminate the communication session and exit the tool (i.e. by selecting "Session/Exit" or the button "End Chat" from the Message Submission Area).

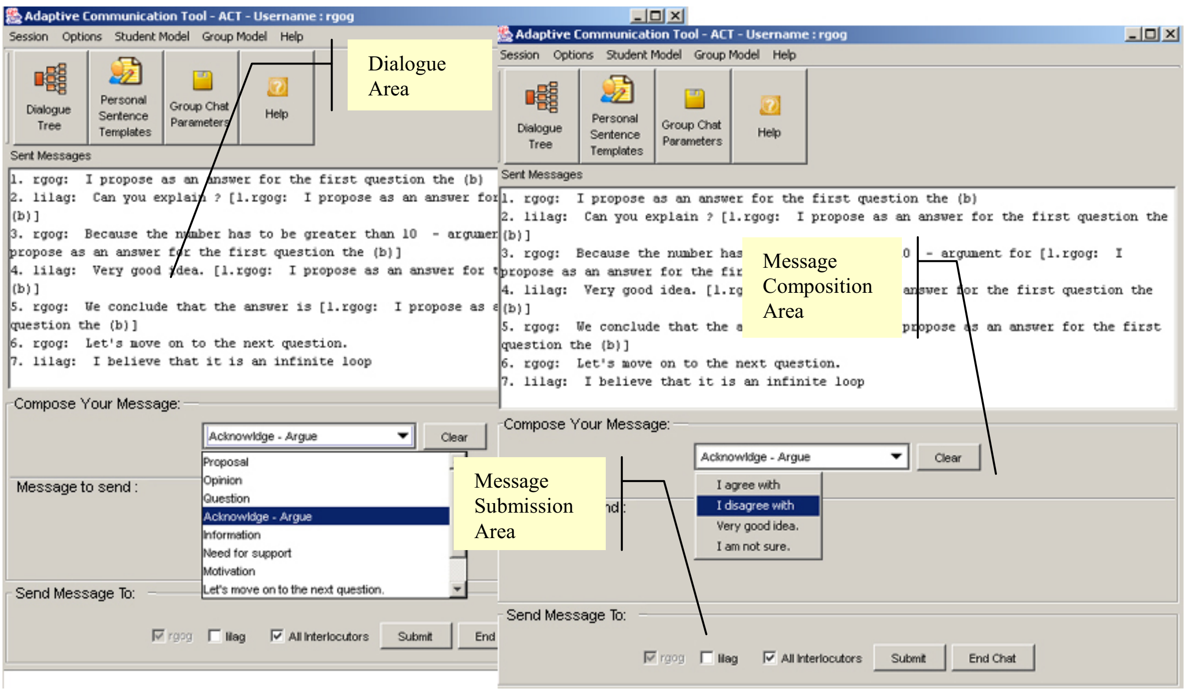

Figure 1: A screen shot of the ACT tool at the communication mode

Predetermined Scaffolding Sentence Templates

In ACT, the structured form of the dialogue is supported utilizing both the sentence openers and the communication acts. For the determination of the most appropriate sets of the scaffolding sentence templates, we followed a research-based approach (Gouli, Gogoulou, Grigoriadou & Samarakou, 2003; Gogoulou, Gouli, Grigoriadou & Samarakou, 2004). More specifically, we conducted three empirical studies during the design phase of the tool in order to determine the appropriate sets of the sentence openers and the communication acts. The supported sets of the SST have resulted from the text-based free dialogues and the feedback received from the participants as well as the experience of the authors. The provided SST are categorized to one or more of the following *discourse categories*: Proposal (P), Question (Q), Reasoning (R), Clarification (C), Motivation (M), Agreement (A), Disagreement (D), Need (N), Opinion (O), and Social Comments (S). The provided sets of the sentence openers as well as the communication acts include:

(i) a subset dedicated to the development of the cognitive skills addressed by the collaborative activity (e.g. the sentence openers: “I propose” , “I agree with”; the communication acts: “Proposal”, “Agreement”).
(ii) a subset dedicated to the development of communication skills (e.g. the sentence openers: “I don’t know. Can you help me?”, “Can you explain?”; the communication acts: “Social Comments”, “Comments on the Activity”), and
(iii) a subset available only to the moderator of the group concerning cognitive as well as communication skills (e.g. the sentence openers: “We conclude that the answer is”, “Let’s move on to the next question”; the communication acts “Answer”, “Group Coordination”).

Communicating with ACT

In the Message Composition Area of the ACT tool, the learner has access to the provided SST and has the possibility to construct the desired message by filling in the required arguments depending on the SST. In particular, regarding the sentence openers, the available SST include:

- [*Sentence*] (fully structured SST): the sentence text as it appears on the list (e.g. “*Very good idea*”, “*I don't know. Can you help me?*”),
- [*Sentence Opener*][Argument] (semi-structured SST): the sentence opener plus an argument which may be an explicit reference to an already sent message appearing on the Dialogue Area (e.g. see Figure 1, “*Can you explain?* [1. rgog: …] ”, where in […] appears the already sent message by the learner) or may be filled in by the learner (e.g. see Figure 1, “*I propose* as an answer for the first question the (b)”).
  In some sentence openers, like “*I agree with……..*”, the [Argument] may consist of both a reference message and a filled in text (e.g. “*I agree with* [reference to an already sent message] free text” where the filled in “free text” specifies further the learner’s belief),
- [*Sentence Opener*][Argument1][*Conjuction*][Argument2] (semi-structured SST): the [*Sentence Opener*] and the [*Conjuction*] are predetermined sentence texts while [Argument1] and [Argument2] may be an explicit reference to an already sent message appearing on the Dialogue Area or may be filled in by the learner (e.g. see Figure 1, “*Because* the number has to be greater than 10 – *argument for* [1. rgog: I propose as an answer for the first question the (b)]”: the first argument has been filled in by the learner while the second one is a reference message),

while regarding the communication acts, the available SST include:

- [*Communication act*][Argument]: the communication act label plus an argument which is filled in by the learner (e.g. “*Proposal*: lets look at the diagram first”),
- [*Communication act*][Reference to a message][Argument]: the communication act label plus a reference to an already sent message appearing on the Dialogue Area plus an argument which is filled in by the learner (e.g. “*Clarification* [15. rgog: What is “st”?]: By “st”, I mean the total number of students”); the [Argument] in some communication acts is optional (e.g. “*Agreement* [3. lilag: The answer is (c)]”).

In case the [Argument] is a reference message, the learner can select the desired one from a pulldown list appearing next to the corresponding SST in the Message Composition Area.

Besides the predetermined sets of SST, the learner may determine his/her own SST in case the available ones do not cover his/her needs. The learner’s determined SST are part of the student’s model and become available each time the learner uses the ACT tool. For each additional SST, the learner determines the text to be displayed, the accompanied arguments and the discourse category (e.g. Proposal (P), Question (Q)). At any time, the learner may edit his/her set, through the option “Student Model/Personal Sentence Templates” from the menu or by selecting the button “Personal Sentence Templates” from the toolbar, and proceed to any modifications (e.g. change the text) and/or deletions (i.e. delete one of his/her own defined SST). In this way, the learner has the possibility to personalize the communication/collaboration process and to exceed any potential restrictions imposed by the use of the predetermined sets of SST.

Adapting the Provided Scaffolding Sentence Templates

According to the Activity Theory, the object of the learning activity, the mediational tools used, the rules and the division of labour followed by the learners, constitute essential elements of the conceptual framework (Engeström, 1987; Cole & Engeström, 1993). In ACT, the object of the learning activity is closely related to the expected learning outcomes, the mediational tools involve any tool that may be used during the elaboration of the activity (e.g. educational software), the rules include the provided sets of SST and the division of labour depends on the model of collaboration followed. Taking into account these elements and having as an objective to support the learners’ communication/collaboration, to prevent floundering and to guide their thinking towards the desired directions, we adapt the provided SST on the basis of (i) the level of the learning outcomes (i.e. cognitive skills) addressed by the activity, (ii) the specific roles that the learners undertake in the context of a specific model of collaboration, and (iii) the educational tool, if any, used for the elaboration of the activity.

On the basis of the proposed adaptation framework, the sentence openers are aligned with the Comprehension, Application and Checking-Critiquing level of the cognitive skills, while the communication acts are aligned with the Creation level and the role that each learner undertake. Also, the communication acts are used to support the learners' dialogue in case learning activities do not explicitly address one out of the four aforementioned levels of cognitive skills, but they rather aim to cultivate to the learners skills in communication, and/or to enable them to discuss/exchange ideas on a specific topic or on the subject/solution of an activity. We support the sentence openers for the Comprehension, Application and Checking-Critiquing level of cognitive skills as these are more concrete. The communication acts are considered more appropriate for higher order cognitive skills or when a model of collaboration with roles is followed since it suffices to guide/assess the learners in terms of their intention/action. We verified and finalized the above design principles of the adaptation framework by the results of the three empirical studies we conducted (Gouli, Gogoulou, Grigoriadou & Samarakou, 2003; Gogoulou, Gouli, Grigoriadou & Samarakou, 2004).

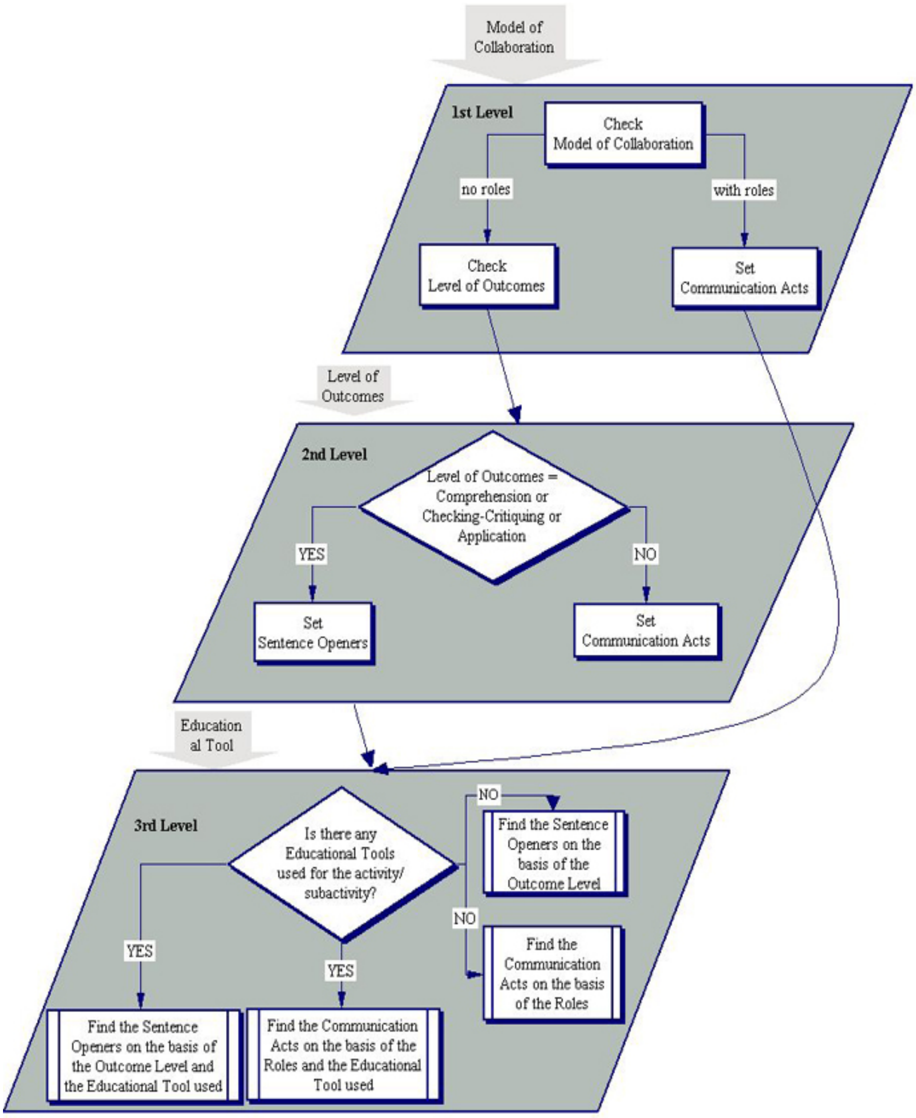

Figure 2. The three-level process of the adaptation framework

The adaptation framework follows a three-level approach depicted in Figure 2:

- 1st Level: At the 1st level, the adaptation mechanism checks if the group members are going to undertake specific roles during the elaboration of the activity/subactivity or to collaborate having the same duties. In the first case, the communication acts are used while in the second case the adaptation mechanism proceeds to the 2nd level in order to check the level of the learning outcomes.

- 2nd Level: This level takes as input and checks the level of the learning outcomes. In case the level coincides with one of the Comprehension, Checking-Critiquing or Application levels, then the dialogue is carried out with sentence openers otherwise with communication acts.
- 3rd Level: Once the provision of sentence openers and communication acts has been specified, the appropriate sets need to be selected. In case of sentence openers, the set of the SST dedicated to the development of cognitive skills depends on the level of the learning outcomes (e.g. the set of the SST for the Comprehension level is different from the one provided for the Checking-Critiquing level). In case of communication acts, when a model of collaboration with roles is followed, the provided SST are adapted to each member according to the underlying role. An additional factor, which influences the set of the provided SST is the educational tool used (e.g. for a concept mapping tool, sentence openers like "I propose to link [concept] to [concept]", "Do you agree with the proposition [concept-link-concept]?" are available).

From the above, it becomes obvious that all the group members (except from the moderator of the group, who has at his/her disposal additional SST compatible to his/her additional duties) have at their disposal the same set of SST if they collaborate having the same duties. For example, in case the activity addresses learning outcomes of the Comprehension level, then all the members of the group may use sentence openers like "I propose", "I believe", "I agree" while in case the activity addresses learning outcomes of the Checking-Critiquing level, then all the members of the group have at their disposal sentence openers like "I propose … because …", "I believe … because …", "I agree … because" urging them to justify their point of view. In case a model of collaboration with roles is followed, the provided SST are different for the group members supporting their roles appropriately. For example, in Figure 3, the two learners with user names "rgog" and "lilag" collaborate according to the "Driver-Observer" model: the "driver" (learner "lilag") is responsible for making proposals, answering to the "observer's" questions, and implementing the task while the "observer" (learner "rgog") is responsible for making comments, asking questions for clarifications, expressing her opinion, giving the answer and guiding the elaboration of the activity. The provided SST are different for the two learners (e.g. "Proposal", "Clarification-Explanation", "Justification" for the "driver" "lilag" and "Question", "Opinion" for the "observer" "rgog").

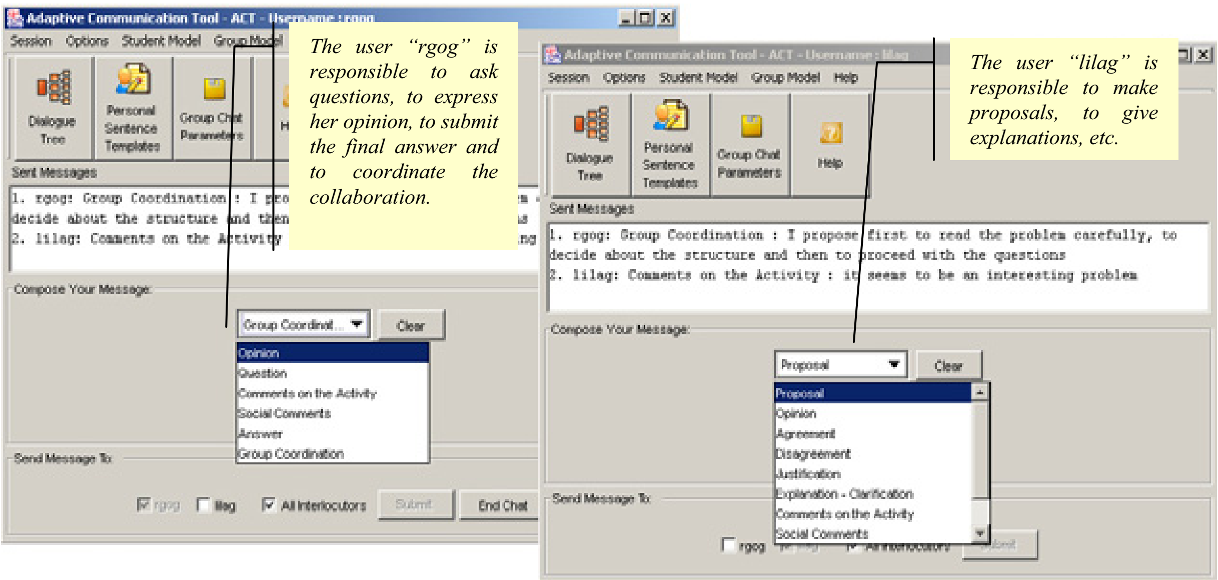

Figure 3. Adaptation of the communication acts according to the roles implied by the collaboration model

Monitoring the Dialogue

In assessing learners' interaction and subsequently their collaboration, the CSCL environments offer mechanisms to automatically trace learners' actions and/or their dialogue. Usually, the data are recorded into log files and may be further analyzed in terms of high-level indicators. According to Jerman, Soller and Mühlenbrock (2001), the CSCL environments may gather data about the learners' interaction and show this information to the learners in a visualization form or process the data and coach/guide their interaction.

In ACT, the learners' interaction is recorded into log files, which are accessible, by the tutor. Moreover, since we are interested in assessing the learners' communication in terms of the skills addressed by the collaborative activity or the collaboration model, we keep records of the learners' messages as these are classified to the aforementioned discourse categories (i.e. Proposal (P), Question (Q), Reasoning (R), Clarification (C), Motivation (M), Agreement (A), Disagreement (D), Need (N), Opinion (O), and Social

Comments (S)) and proceed to their quantitative analysis. The data resulted from the analysis are accessible both to the learners and the tutor and concern the number of messages sent by each group member for each one of the discourse categories (e.g. number of Proposals), the groups that have performed the specific activity/subactivity, the models of collaboration followed in the context of the specific activity/subactivity, etc. The learners can have access to these data at any time during their communication through the option “Group Model”.

As the learners’ communication is carried out, their messages are visually represented in a tree structure, grouped according to the reference message. In particular, ACT supports a facility for the automatic construction and update of the Dialogue Tree as the learners submit their messages. The messages are grouped into sub-trees according to the message that they are referring to. The learners can have access to the Dialogue Tree at any time during the communication through the option “Options/Dialogue Tree” or through the button “Dialogue Tree” from the toolbar. The main advantage of such a graphical representation of the dialogue is that the learners can see the dialogue in a different form, can trace the sequence of the dialogue more easily and can have a clear view of the dialogue progress. Also, the Dialogue Tree can stimulate the learners to reflect on their dialogue and improve their participation. In Figure 4, a screen shot of a dialogue tree is presented.

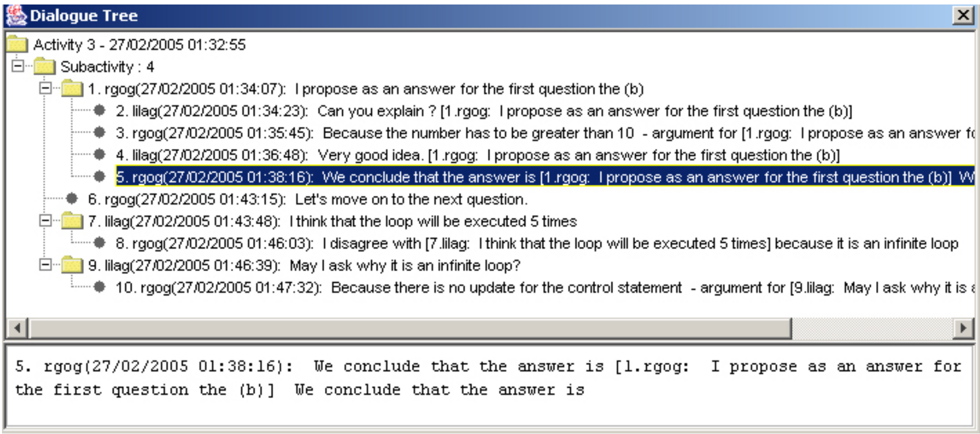

Figure 4. The Dialogue Tree represents the learners’ debate in a graphical form

EVALUATING ACT

During the formative evaluation of the ACT tool, an empirical study was conducted. The aim of the study was two fold: (a) to investigate whether (i) the predetermined set of the SST cover the learners needs in terms of their completeness, understandability, accessibility and facilitation of the dialogue, (ii) the adaptation framework is appropriate and complies to the learners’ communication preferences, and (iii) the provided facilities (Dialogue Tree and enrichment of the SST) serve their aim, and (b) to analyze the learners’ dialogue in terms of investigating the proper use of the provided SST, the coherence of the dialogue and the degree of the learners’ participation.

The empirical study took place during the spring-semester of the academic year 2003-2004 in the context of the postgraduate course of “Distance Education and Learning” at the Department of Informatics and Telecommunications of the University of Athens. Thirty students participated in the study, coming from a range of backgrounds and having different expertise in the use of communication media. The duration of the study was 4 hours; each student worked on his/her own computer. We grouped participants into two-person (9 groups) and three-person (4 groups) teams; one of the members undertook the role of the moderator.

The working sheet included (a) a brief description of the ACT tool, (b) a description concerning the form of the dialogue followed and the SST provided, (c) four collaborative learning activities, and (d) a questionnaire concerning the facilities provided. Upon the completion of each learning activity, the students were asked to answer a series of questions (multiple choice and open questions) concerning the usability of the tool, the communication process, the role of the moderator, any problems identified, etc. For the first three activities, the students of each team had the same duties and acted equivalently while in the context of the fourth activity, specific models of collaboration were followed, i.e. the “Questioner-Responder” model for the two-person teams and the “Questioner-Responder-Assessor” model for the three-person teams. The first activity asks the students to follow a specific scenario enabling them to explore the facilities of the tool and become familiar with the form of the provided SST. The second learning activity addresses cognitive skills, which concern the students’ ability to remember and understand things (Comprehension level) and therefore sentence openers were used. The third activity urges the students to think of/reason/discuss/exchange ideas on a specific topic using communication acts. Finally, the fourth activity addresses cognitive skills, which concern the students’ ability to check the correctness and the completeness of a given “product”, to reason about their opinion and to proceed with any necessary modifications of the "product" (Checking-Critiquing level and Application level). According to the adaptation framework, communication acts were used in the fourth activity as the models of collaboration implied specific roles.

Empirical Results

The empirical results, concerning the first aim of the study, were drawn from the analysis of the students' responses on the questions accompanied each collaborative learning activity and the questionnaire included in the working sheet. The analysis of the students' answers concerning the provided sets of the SST is depicted in Figure 5. More specifically,

- the majority of the students characterized the <u>completeness</u> of the predetermined sets of SST as sufficient and rather sufficient (90% for sentence openers and 87% for communication acts).
- a considerable number of students characterized the way the SST are presented and especially the <u>localization</u> process of the desired SST, as easy (sufficient and rather sufficient). However, 25% of the students found difficulties to localize the appropriate sentence opener to be used (characterized the specific criterion as average and rather insufficient). They considered that the provided SST could be grouped instead of presenting them in a list. This result was taken into consideration and we redesigned the form that the SST are provided to the learners (a group formation of SST is supported; see Figure 1).
- most of the students (70% for sentence openers and 94% for communication acts) believed that the use of the provided SST <u>facilitated their dialogue</u> (characterized the specific criterion as sufficient and rather sufficient). Although a small percentage (6%) of the students believed that the provided set of communication acts made the communication process difficult, the corresponding percentage for the set of sentence openers was quite high (30%). The students' answers indicate that the size, the form and the number of arguments of the sentence openers may cause difficulties; on the contrary, the set of the communication acts is smaller and the form as well as the number of arguments to be filled in is simpler than in the case of the sentence openers. It is important to mention that most of the students, who found difficult the use of sentence openers, have high degree of expertise in the use of chat tools and prefer the free dialogue.

As far as the application of the adaptation framework is concerned, the majority of the students (approximately 80%) considered the provision of the sentence openers or the communication acts in line with the context of the activities. A percentage of students (approximately 10%) argued that the communication acts (sentence openers) could also serve the underlying outcomes of the second (third and forth) activity and some of the students (10%) preferred the sentence openers (communication acts) instead of the provided communication acts (sentence openers).

Regarding the facilities provided to the students, the analysis of the students' answers showed that

- a considerable number of students (76%) found the facility of connecting a message with an already sent message very useful since it reduces the typing load. However, 24% of the students characterized the specific facility as indifferent because they believe that the complexity of the composition message process is increased.
- the majority of the students (83%) considered the capability of the ACT tool to group messages into sub-tress and to represent the dialogue in a visual graphical form (Dialogue Tree) very useful because it enables them to monitor the dialogue in an organized and enjoyable manner, to evaluate the collaboration process more easily and to proceed to interventions in order to improve their participation. However, a number of students (17%) mentioned that there was no need to consult the Dialogue Tree.
- most of the students (66%) characterized the facility of enriching the predetermined sets of sentence openers and communication acts with their own phrases useful. Approximately, 50% of them took advantage of the specific facility during the elaboration of the activities, defining one or two phrases.

The analysis of the students' dialogues (log files and dialogue trees) revealed the following:

- The majority of the exchanged messages indicate that the provided SST were used in correct manner. It seems that the students understood the underlying intention and they selected carefully the most appropriate SST. In one case, one of the group members was quite eager to participate and was inclined to conclude the main points of the discussion, although he was not assigned the role of the moderator (since he didn't have at his disposal such a phrase, he made use of the possibility to define his own phrase).
- The dialogues presented sequential coherence as the students listened carefully to their interlocutors and related their answers to the appropriate message. In some cases, the depth of the dialogue trees was five levels deep showing that the students were able to agree/disagree, justify their opinions and follow up the others' contributions. To this direction, the provided facility of connecting a message with an already sent message helped quite a lot. However, there were a very few cases that the dialogue seemed to be quite flat as one of the group members didn't not contribute in time while the rest two members continued the discussion.

- All the members of each group participated actively in the discussion. The students appreciated their interlocutors' opinions (e.g. they used the phrase "Very good idea") and they perceived the need as well as they were motivated by their interlocutors' questions to elaborate on their opinions.

Although the above results are preliminary, the provided SST as well as their usage and accessibility seem to be satisfactory and they caused minor difficulties resulting into coherent dialogues. Also, the adaptation mechanism proved to be appropriate regarding the selected set of the SST and the facility of enriching the predetermined sets of SST with the learner's ones, gives a degree of freedom to the learners. The visual representation of the Dialogue Tree supports the monitoring of the dialogue and the students claim that serves as a means to reflect on the collaboration process.

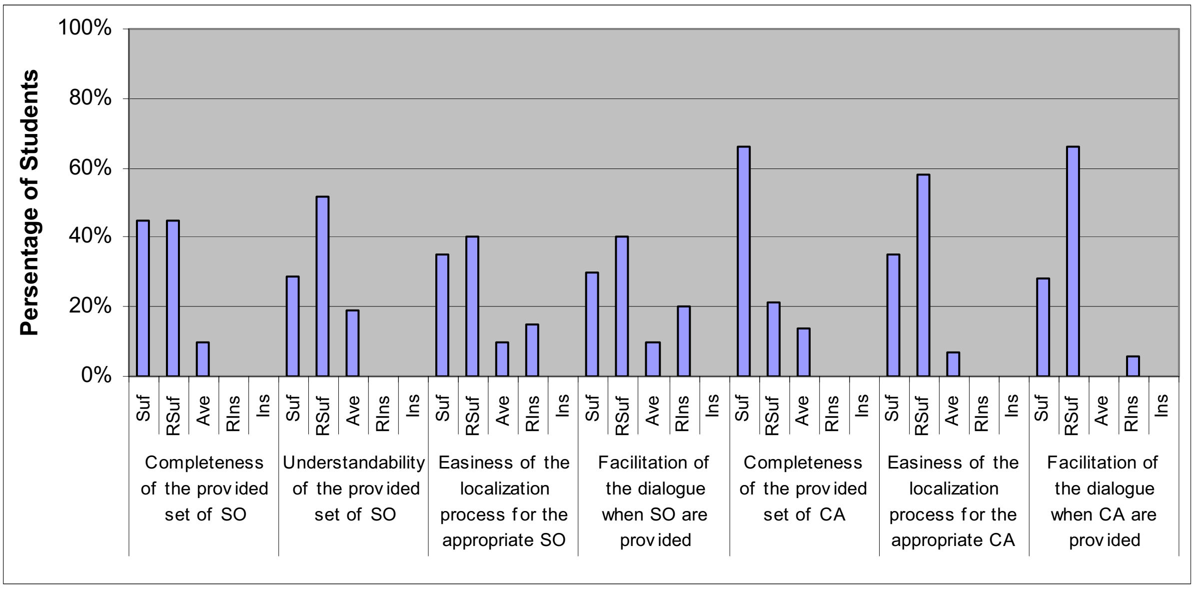

Figure 5. Results concerning the provided set of sentence openers (SO) and communication acts (CA). The abbreviation Suf stands for Sufficient, RSuf for Rather Sufficient, Ave for Average, RIns for Rather Insufficient and Ins for Insufficient

CONCLUSIONS AND FUTURE PLANS

In this paper, we presented ACT, a synchronous communication tool enriched with adaptive capabilities. The discriminative characteristics of the ACT tool are: (i) the use of both sentence openers and communication acts for the implementation of the structured dialogue, (ii) the adaptation of the provided sets of the SST according to the learning outcomes addressed by the collaborative learning activity, the model of collaboration followed by the group members, as well as the educational tool used for the elaboration of the activity, (iii) the capability of alleviating the possible restriction of the learners, imposed by the structured form of the dialogue, by enabling learners to define their own SST and enrich the provided sets, and (iv) the monitoring of the group dialogue and its graphical representation through the Dialogue Tree. The provided facility of connecting/grouping messages by making explicit reference to a previous message as well as the capability of defining SST enhances the contextual structure of the exchanged messages and enables the learners to follow the communication forms that match as much as possible their own preferences and needs. Our near future plans include the enhancement of the adaptive and adaptable capabilities of the tool with respect to the learners' preferences and interaction behavior (e.g. support of the free dialog after a negotiation of the group members) and the enrichment of the monitoring facilities with additional features regarding the visualization of various quantitative collaboration indicators, such as the density of interaction and the degree of collaboration.

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The Effects of Electronic Communication Support on Presence Learning Scenarios

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Abstract. This paper investigates in the effects of using electronic communication forms in web-based environments. Following the idea of triangulation, we used qualitative methods, statistical analysis and Social Network Analyses to explore the patterns of communication within one selected case of a mixed presence/web-based university course. The results show that while an isolated perspective does not suffice to explain the complex processes, taking more perspectives into account in a combined and integrated way provides a better understanding of technology enabled communication and interaction.

INTRODUCTION

In current educational practice, web based environments are an established means to accompany learning scenarios. In contrast to other computer based support methods, web based tools have some inherent practical advantages: they normally do not require the user to install any software, and a significant number of today's learners already has some experience in browsing web pages and therefore is used to the underlying usage patterns.

In learning contexts there are numerous variants of how the WWW is used. Different functions include web pages serving as a more or less static information source, web-based intelligent tutoring systems where the main purpose of the system is to teach rather than to be a learning resource, and environments which take into account social perspectives of learning and offer means for communication or collaboration as a central element of the web based learning support (Madrazo, 2003; Scardamalia, 2004).

In addition to these differences in the *function* of existing web based environments for learning support, also the usage *context* of these systems varies considerably: one characteristic factor is the learning group size, which can vary between very small groups (or even isolated single users that to not interact with others) and large communities with their special needs (Gaudioso & Boticario, 2003). Further distinguishing criteria include the course type (e.g., lecture vs. seminar), and the age of students. In addition, some approaches are related primarily to distance learning scenarios, while others focus on the support of presence courses.

Today's support of presence lectures at university level via web based environments is a typical intermediate case between presence and distance learning situations, sometimes denoted with the term "blended learning" (Sauter, Sauter & Bender, 2004): often, the lecture is done physically, but a lot of supporting actions are delegated to a web-based environment due to lack of time, university staff, or other constraints. Students and teachers can make use of web-based support environments in various ways (like, e.g., communication facilities, resource collections, the management of exercises if appropriate, etc). One goal of this paper to find out whether this web based support *improves the learning results* of the students.

Pinkwart et al. (2005) present some investigations that analyze the interrelations between active usage of the forum embedded in the iPAL (internet Portal to Augment Learning) web portal, and the student's final grade in the examination. Indeed, a positive correlation was observable. One of the particular results showed that an above-average system usage correlates positively with a good grade. However, interesting questions remain: In order to thoroughly understand the relations between the usages of the web based environment by learning groups and the learning outcome, we redesigned iPAL to be able to conduct a more detailed analysis of system usage and its comparison to learning outcomes.

THE SETTING: LECTURE AND WEB-BASED COMMUNICATION ENVIRONMENT

The course that was investigated in this paper is the lecture "Software Engineering" held in the summer term 2004 at the University of Duisburg-Essen in Germany. The course is taken mainly by second year students of computer science. It consists of a lecture with accompanying exercises being part of the presence learning scenario.

The exams were conducted in a mixture of small group (3-5 students) projects of 4 weeks duration and oral exams taken after the project submission. To support the small project groups with a proper communication infrastructure, each group was given a small group discussion forum, a Wiki, and CVS server access:

The small group *discussion forum* was meant for communication within the project groups and with their assigned “customers”, our student tutors taking the role of the customer of the software project to be developed. The *Wiki* was introduced to the students in the lecture as a means of co-constructively editing and refining living documents, which can be used to find common ground on specific terms by defining their interpretation. The *CVS server* supported the distributed software development by taking responsibilty of version managment and conflict management in case of concurrent modifications of source codes and project documents.

In the following sections of the paper we will analyse and discuss the usefulness of these communication facilities and their impact on group structure and dynamics as well as on the outcome of the exams. This is meant to shed light on our preliminary results (Pinkwart et al. 2005) that showed that a strong participation in the lecture’s discussion forums correlated with the achieved grades. At this point we investigate more deeply in the use of a variety of support tools for project work. Our hypothesis is that using computer-based communication infrastructures facilitates the success of project work: here, we put a specific focus on relating the different communication means with each other. Especially the question if there is a key communication infrastructure crucial for success, or if synergy / balance of different tools proves to be effective is a focus in our study.

The methodology of the study can be characterised as a mixed method design, following the idea of triangulation (Denzin 1980). The decision was to use qualitative methods, statistical analysis and Social Network Analyses (Wassermann and Faust 1994). This research design allows to use the results from one applied methodological approach as interpretation context for the other methodological pathways.

Qualitative analyses of the forums and the Wiki: Qualitative methods are suitable for understanding new phenomena. In triangulation designs qualitative methods are usually used with the aim of building typologies and hypotheses. In our case, the building of hypothesis was guided by the question of differences between the typologies we found, and also by asking how these are affected by other factors.

Social Network Analysis (SNA): In contrast to quantitative methods which analyse structures indirectly through the operationalised properties of the analysed cases, SNA allows the reconstruction of social structures, e.g. communication paths. In our study we used the typology derived by the qualitative analyses for sampling the most interesting groups (in the sense of the highest variance) in the way of how they organised their project.

Statistics: Based on categorisation of groups with different types of Wiki and forum usage by qualitative analyses, statistical analysis serves us to explain differences between groups, done by formulating hypothesises.

Long term statistical analysis: Since iPAL had already been used to support a past course, we decided to compare the results of both courses. In addition to the result comparisons, we were also able to make some long term analysis, because 75% of the students from the actual course were also present at the past course.

The qualitative analysis was mainly done by long term observations through the teaching staff and by analysing the content of the Wiki and the forums. The data for the SNA and the statistical analysis was extracted from the database used by iPAL and the CVS log-files.

Qualitative and Quantitative Results from Wiki and Forum Usage

To understand how Wiki and the forums were used within the different project groups, we analysed the content and the creation process through its versions as well as the forums qualitatively. We found out that the Wiki usage varied widely in separate dimensions:

On the one hand the *interactivity of the construction*, i.e. number of different authors, number of versions and scope of changes between versions varied: some groups made small and frequent updates/modifications, some had few but rather big changes between versions. Additionally some Wiki pages seemed to have been the “property/responsibility” of one person, because they were edited exclusively/mainly by one person.

On the other hand the *content* and thus the *purpose of the usage* varied: we found and indexed four categories of usage of the Wiki: *project management, glossary construction, reference lists*, and/or *coding conventions*: In *project management*, the Wiki is used to coordinate team members’ activities and document their planning. Updates are usually done when replanning, rescheduling and making counterproposals. The final version is (probably) the documentation of the project process as it happened in reality. For *Clarification of terms/Glossary Construction* the Wiki is used to find a common ground and understanding of central terms and concepts for the project work. Updates are usually done when introducing or defining new terms. The final version is a glossary of used concepts and terms of the project. *Reference List* usage provides a common index to outside resources. Updates occur when giving new references and links. If used for *coding conventions*, a style guide for programming and/or documenting code is created. Updates are usually done when conventions are proposed, changed or retracted. The final version represents the conventions to be used within the project.

We analysed the interactivity of construction and the usage type of the different project groups. 10 out of 20 project groups used the Wiki extensively, while 10 used it hardly or not at all. Some groups mainly communicated outside of our support environment, e.g. via ICQ. For the 10 groups using Wiki we manually indexed the type of usage with the following results:

Table 1 – Categories of Usage for the project groups' Wiki (N=73, Average Scores in Parentheses)

	Purpose of Usage			
Interactivity of Construction	*Glossary Construction*	*Project Management*	*Reference List*	*Coding Conventions*
Few versions, large differences	Group A (71.12) Group K (75.8)	Group A (71.12) Group G (65.5)	-	Group F (84.625)
Frequent versions, small differences	-	Group B (68.667) Group D (58.375) Group E (77.625) Group H (d.n.f) Group I (85.25)	Group C (63.0) Group I (85.25)	-

In the case of the forums' analysis (all 20 groups used this communication means), four different types of usage could be found. The first category shows a very structured behaviour of using the forums. We could usually find more threads than in other groups. The topics of threads were structured but the threads were short. The second category posted just a few but long threads. The third category posted there were both a high number of threads and some of the threads were also very long. In this case we could also observe a differentiated topic structure. The fourth category used the forums just for planning meeting dates. We classified each group according to these categories.

It is significant that category 3 has the highest average of postings (11.13) and also the best results with respect to the average score (87.43). This category produced also most total files (383) in the CVS and second most versions after category 1. There is another interesting result by looking at category 2. One of the project groups within category 2 decided to use the agile programming paradigm and another project group chose a modular approach based on the division of labour. Putting them to a subcategory, this subcategory reached a score average of 86 while the other two project groups within category 2 which had not followed a systematic approach reached an average of only 53 points. This bias has to be mentioned because the agile approach usually shows an extensive face to face communication structure and the modular approach shows a rationalized communication structure in favour of the division of labour concept. Category 4 (no use of the forum for content structuring) had the smallest average score (66.88) of the categories.

Counting both concepts together yields that the project group with the highest score average (93 points, $T = -6.29$ significant at $P < 0.001$) belongs to category 1 of the forum characterization and showed no extensive Wiki usage at all. All members of this group were also present at the course we analysed last term. The group with the fewest average score (40 points, $T = 3.51$ significant at $p = 0.001$) used the forum but not the Wiki. It is also interesting that there is no significant difference in the average scores by categorizing the project groups into categories which just used Wiki or forum or used Wiki and forum both.

Social Network Analysis

For our plans to investigate in the patterns of usage of the discussion forum and the resulting communication structures, we followed the method of Social Network Analysis (Wassermann and Faust 1994, for applications in CSCL: Reffay and Chanier 2003). For this study we decided to concentrate on "direct active communication", which manifests itself in a discussion forum by a direct answer of an actor to an actor's posting. For detailed analysis of the communication structures we had the general discussion forum open to every user of the iPAL system and additionally separate forums for each project group and their "customer" (cf. Section The Setting). We will focus on selected SNA features which are applied to the general forum and contrast/relate it with a few project groups with distinctive project processes, communication structures and project results. Among the SNA traits are the centrality of one actor, the centralization of the respective network, and the prestige of an actor, all of them computed based on the degree within the graph.

The general discussion forum had 64 persons creating 276 postings. The computed value for degree-based centralization is $C_D = 0.283$ (0 means a completely balanced network, 1 a completely centralized network). This shows that the network had some "keyplayers", but also that in general the network was not dominated by any actor. The average of individual actors' centrality was $Avg(C_D(n)) = 0.044$, which means that the general centrality of actors was quite low, so nobody would be called "hub" in this network.

For the project groups, which typically consisted of 3-5 students and one "customer", we were mainly interested in differences between the groups and relations between communication structure, project organisation, and final outcomes. Driven by our qualitative categorization and the concept of maximal variance, we present 3 selected groups (see figure 1) that are distinctive with respect to the way they communicated and their general project organisation:

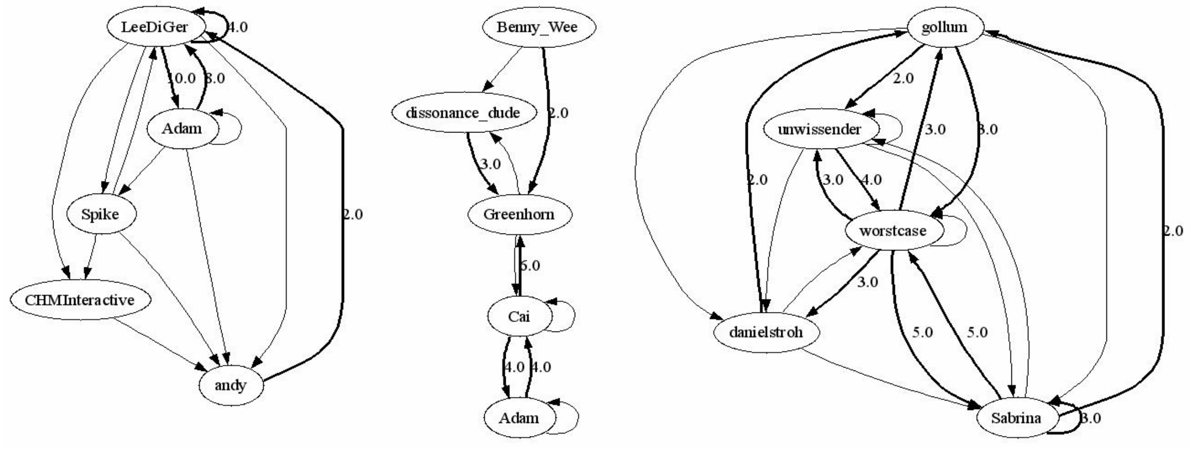

Figure 1 Sociograms of groups (left: group1, middle: group2, right: group 3)

Group 1 (no Wiki usage, little CVS, long threads with few topics) had a centralization $C_D = 0.5$ of the network with one student as central actor (centrality C_D (p) = 1.0 and prestige $P_D = 0.75$), the customer (Adam) with a small prestige of $P_D(c) = 0.25$ (in fact the smallest in this network) and other actors with centrality ranging from 0.25 to 0.75, prestige from 0.5 to 1.0. This group had indeed problems with internal communication (inside and outside the iPAL system), which led to a limited involvement of their customer, separate development of project subparts and integration problems for the project submission. This resulted in an inferior project outcome than the individual skills of the group members would suggest.

Group 2 (no Wiki use, highest CVS, differentiated topics with short threads) shown in the sparsely connected graph had a small centralization $C_D = 0.125$ of the network and a low individual centrality $C_D(n)$ of the members ranging from 0.25 to 0.5. The prestige $P_D(n)$ varied from 0 to 0.75, with the customer having 0.25 in both centrality and prestige. This can be explained because of the specific process and distribution of labour this group chose: One of the members (Cai) was assigned as "the Key Account Manager" and exclusively communicated to the customer (Adam), both in forum and personal meetings. Since the planned project process was followed consequently the project outcome resulted in the highest score of all the project groups. This group used other support facilities we provided extensively, especially the CVS with more than 140 files and 1400 versions.

Group 3 (extensive Wiki and CVS usage, differentiated topics with long threads) shown in the densely connected graph had also a small centralization $C_D = 0.1875$ but a consistently high individual centrality $C_D(n)$ ranging from 0.75 to 1.0 and prestige $P_D(n)$ between 0.75 and 1.0. The customer (Sabrina) was intensively involved with centrality $C_D(c) = 0.75$ and prestige $P_D(n) = 1.0$. All provided support facilities led to a well-coordinated project that scored second among all the project groups.

Reviewing the SNA results, we found that the exclusively structural analysis might not be sufficient to explain process and outcome of the group's work, but with the additional information we had as creators of the course, most of the phenomena could be explained utilizing both SNA and the process knowledge. This result indicates that especially in mixed presence/web-based scenarios, SNA can be helpful to understand and interpret communication structures.

Statistical Analysis

The dataset represents 20 project groups including the average score, average number of postings, the number of the files produced and the number of file revisions made by each group. The interesting outcomes are a) that there is a middle strength correlation (0.541 significant at 0.05 level, Spearman) between number of files each group produced and the average score each group reached in the course, and also b) a middle strength correlation (0.571 significant 0.05 level, Spearman) between CVS revisions made by each group and the average score each group reached. Another hypothesis was a correlation between the average number of postings for each group and the CVS usage behaviour. Yet, correlations between the average number of posts and the number of files or versions produced using the CVS system could not be observed.

As mentioned in the section about research design, the approach presented in this paper is particularly based on an evaluation study that was carried out last term. Thus it is self-evident to compare the current results with the past evaluation. We compared the results from Pinkwart et al.(2005) with our current study:

In this case we can observe that there was a stronger relationship between the number of postings and the average score (0.485 significant at 0.001 level, Spearman) than in the current study (0.320 significant at 0.01 level, Spearman). This result led us to assume a fortification of personal relationships, and thus more direct (for us non-observable) communication between the students, since 75% of the students in the recent course know each other from the last course. The hypothesis that this is caused by usage of Wiki could not be proved, since the students who used Wiki did not show a significantly different posting behaviour in the average than the students who didn't use the Wiki. This result leads us to look at the difference between the 75% of the students (N=55) which were present in both courses. In this case the students have received an average score of 71 points in comparison to the last course they reached an average of 61 points. This difference is significant ($T= 4.72$, $p < 0.001$) and there is correlation between the scores of the pairs (0.643, $p< 0.001$) that can be interpreted that in most of the cases (students) who received a high average in the past course received a high average in the current course, too. On the other hand we could not see a significant difference according to the posting behaviours within the compared courses.

CONCLUSION AND OUTLOOK

In this paper we used mixed method design to evaluate communication processes and structures within the web-based support system iPAL that was used for a presence university course. Following the idea of triangulation, we utilized qualitative methods, statistical analysis and Social Network Analysis. Qualitative methods were used to classify the usage types of the communication facilities Wiki and discussion forums. Based on these categories, we selected project groups with maximal variance of their communication behaviour and conducted Social Network Analysis to explore communication structures in detail. The SNA of the whole learning community produced a non centralized network, which complies to the large variety of communication facilities student subgroups used in the project work, according to their own choice. This degree of freedom was intended by the pedagogical approach. Indeed this is supported by the fact that no single communication form proved to be superior. In fact the combined usage showed to produce better results with respect to the final scores. These findings indicate that more aspects of the respective communication forms should be taken into account to be able to compare them properly. To reduce the complexity of data collection and aggregation of these multi-perspective analyses, we plan to explicate standard procedures for the follow-up studies, such as automated processing of forum postings as well as representation formats suitable for analysis.

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From Parallel Play to Meshed Interaction: The Evolution of the eSTEP System

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Abstract. In this paper, we describe the evolution of the eSTEP system. The eSTEP system is an integrated online learning environment for teacher education that provides videocases of classroom practice, an online learning sciences hypertext, and a collaborative problem-based learning environment. The central tool in the problem-based learning environment is the group whiteboard. In face-to-face PBL activities, a whiteboard serves to focus negotiation and represent current understanding. Seeking to offer the same functionality online, we adapted the structure and functionality of a basic whiteboard to easily allow students to exchange and develop ideas online, and effectively represent current understanding. This tool serves as the focus of negotiation in face-to-face PBL but required considerable adaptation to serve this function in an online environment. This paper describes the refinement of the whiteboard and the concomitant refinement of our theory of how students learn through meshing the conceptual ideas of the learning sciences with perceptual information from the problems of practice.

Keywords: problem-based learning, scaffolding, design principles

INTRODUCTION

Problem-based learning (PBL) is an effective approach to collaborative learning in professional education environments (Hmelo, 1998; Hmelo-Silver, 2004, Derry & Hmelo-Silver, in press). It provides a cognitive apprenticeship in which students learn through solving problems and reflecting on their experiences. Students work in small collaborative groups with a facilitator who scaffolds the learning process. PBL promotes effective transfer because students repeatedly bring together conceptual ideas underlying a domain with visions and plans of professional practice as they construct what we call a meshed schema representation (Derry, in press; Derry & Hmelo-Silver, in press). In PBL, learners study and discuss concepts in depth, applying them to practical problems and they become highly practiced in recognizing how these ideas and reasoning are used in varied problems across many *cases* of practice. In our work with pre-service teachers, many instructional video cases are provided, to give pre-service teachers opportunities to experience and encode them perceptually within complex contexts similar to what they will actually experience (Derry, Hmelo-Silver, Feltovich, Nagarajan, Chernobilsky, Halfpap this volume). These activities help learners build up schemas in which different and varied kinds of knowledge (declarative, procedural, and perceptual) are meshed together in ways that emphasize the deeper conceptual themes). This concept of mesh was not a part of our initial instantiation of the PBL in the eSTEP system. The goal of this paper is to present a design narrative that shows how our design of the eSTEP system evolved, as well as how our theory about learning from video was refined. All the design and testing rounds were with different groups of preservice teachers, both at Rutgers University and at University of Wisconsin-Madison (see Chernobilsky, Nagarajan, & Hmelo-Silver, this volume; Derry et al, , this volume). Our goal was to help the preservice teachers understand how the learning sciences applied to classroom practice. Our data for the initial rounds of work were indicators of engagement—posts in the eSTEP environment. For later rounds, we collected detailed process data (Chernobilsky et al; this volume; Hmelo-Silver, Chernobilsky, & DelMarcelle, 2004) as well as information about learning outcomes (Derry et al., this volume).

PBL has its origins in medical education. In this environment, typically a group of 5-7 students work with their own facilitator (Barrows, 2000). The facilitator provides instructional guidance by scaffolding the learning process. Much of this scaffolding is in the form of metacognitive questions that help structure the group's learning and problem-solving processes, help them manage their time, and push them to think deeply (Hmelo-Silver, 2002). In addition to the scaffolding provided by the facilitator, a structured whiteboard helps support the group's learning and problem solving. Typically, this whiteboard has four columns: facts, ideas (hypotheses about causes of problems and solutions), learning issues (concepts that the students need to learn more about to solve the problem) and an action plan (a “tickler” list). The whiteboard provides a focus for students to negotiate and represent their understanding of the problem and possible solutions, and it inherently then guides discussion (Dillenbourg, 2002; Hmelo-Silver, 2003; Suthers & Hundhausen, 2004). Other settings are not as privileged and require additional scaffolding to support PBL in larger classes. Because of the small group nature and close instructional interaction of PBL, it is resource intensive, requiring a larger instructional staff to support the same number of students than a more traditional instructional method (Steinkuehler, Derry, Hmelo-Silver, & DelMarcelle, 2002). The first author had engaged in PBL in her face-to-face educational psychology class for two years using paper cases and had identified some areas of weakness that computer-based scaffolding might address (Hmelo-Silver, 2000). Rather than an assigned facilitator, Hmelo-Silver used a wandering facilitator model. This only allowed short periods of time with each of the groups and reduced the amount of scaffolding and monitoring that could be provided. In addition, the paper cases were not always sufficiently complex for students to see how concepts applied in a variety of cases. Thus, prior to creating an online PBL version, we identified several problems that we hoped an integrated online environment could address. But just putting PBL online required careful consideration of how the environment could serve to structure the process.

A major adaptation was a move from synchronous face-to-face discussion to an asynchronous online discussion. There were two reasons for this adaptation. First, students in an asynchronous discussion tend to be more reflective (Andriessen, in press; Bonk et al., 1998). Second, it is easier for `a single instructor to facilitate multiple groups in an asynchronous environment than in a synchronous environment. Research on scaffolding suggested that domain specific scaffolding might be more effective in the online environment (Hmelo & Guzdial, 1996, Hmelo-Silver, in press, Reiser, 2004) than the general whiteboard used in face-to-face PBL. To accomplish this, we needed to design a whiteboard that would specifically promote principled instructional design activities. Thus we wanted to use an online whiteboard (and other tools) to help structure the collaborative PBL process and promote productive learning interactions (Dillenbourg, 2002). We wanted to strike a balance between productively constraining the group interaction while allowing the process to remain student-centered.

ROUND 1: MOVING ONLINE WITH PARALLEL PLAY

Our initial goal was to do a simple online adaptation of a modified PBL activity structure to help preservice teachers learn how to apply the learning sciences to teaching practice. This activity structure focused on having students use the learning sciences to interpret, evaluate, and redesign actual video cases of k-12 classroom instruction. We wanted to use video cases to make the problems more realistically complex than our paper cases afforded. To support small group interaction, the initial online environment included a personal notebook for individuals to record case analyses and reflections, a structured group whiteboard to serve as a focus for negotiation as the whiteboard did in a face to face environment, and an asynchronous threaded discussion to allow students to engage in less structured discussion. For instructional resources, in addition to standard textbooks, students had access to the Knowledge Web, which is an online hypertextbook focusing on the learning sciences. In sum, our initial system had five parts: an individual notebook (see Figure 1a), a group whiteboard (Figure 1b), a threaded discussion, a videocase library, and a learning sciences hypermedia, the Knowledge Web (DelMarcelle, Derry, & Hmelo-Silver, 2002; Derry, in press).

<table>
<tr><td colspan="4">Individual Whiteboard</td></tr>
<tr><td colspan="2">Observations</td><td colspan="2">Initial Redesign Ideas</td></tr>
<tr><td>What facilitated learning?</td><td>What hindered learning?</td><td>What should be done.</td><td>Why it should be done.</td></tr>
</table>

Figure 1a. Round 1 Individual Whiteboard

The first implementation of PBL was a pilot activity that required students to analyze a video case of science instruction. In this case, the teacher was not achieving the learning outcomes that he had hoped for. The problem required students to redesign the video case, based on an analysis of the case from a learning sciences perspective. To facilitate students’ initial analyses and subsequent group analysis and redesign, we designed a structured individual notebook designed to scaffold the initial analysis. To promote argumentation, the group whiteboard provided a space for students to post their ideas and a place for students to post notes that identified strengths (pro) and weaknesses (con) of the proposal.

The specific prompts chosen in these scaffolds created representations that we had hoped would bias the discussion in productive ways. The initial activity structure was quite simple. It had three phases. Students were asked to do an individual case analysis, a collaborative analysis in the threaded discussion, and to develop a redesign proposal in the whiteboard. This activity design was tested in two groups that were experienced in using PBL in a face-to-face format. This particular PBL activity was their last of six that they were required to complete for their educational psychology course. The activity occurred entirely online.

While both of these groups had functioned effectively over the course of the semester in a face-to-face format, they were not terribly effective online. We identified three potential reasons. First, we observed a parallel play phenomenon—that is, the students did not coordinate their postings. Students were moving through the activity on parallel paths without meaningfully interacting with one another. For example, one student might post, another student might post another note 1-6 days later as the facilitator (CHS) noted in her journal "I am still frustrated with the parallel play aspect of the activity. I think that first few times students do a problem like this they will need a lot of structure in the task, in terms of milestones and required numbers of notes in which part of the site. As I have said before, a big problem is the disconnect between the web board and whiteboard. I don't know if we could use the idea of anchored collaboration…" The students' proposals for solutions tended to be somewhat independent of each other. This is antithetical to the central tenet of PBL, that ideas are collaboratively reviewed, negotiated, and decided upon. Second, the structure of the activity was very broad. Norms of interaction did not simply translate to the online environment. Although two weeks were allotted for the group phase of the activity, the students tended to think of that as a deadline and some students did not post anything until the final date. Unlike a face-to-face format in which silence is awkward, in an online environment silence is difficult to break. The facilitator spent a great deal of effort emailing students to encourage them to get online and join the discussion Third, it was difficult to facilitate because of technical issues. For example, the facilitator could not post to the group whiteboard. So, if a student posted something to the whiteboard, the facilitator could only question that in the threaded discussion and the context for the question was lost.

<table>
<tr><td rowspan="2">Peter: I think we should instill more questioning in the class. The questions the teacher asks at best seem to be short answer.</td><td>Pro:
Peter: Engaging students in dialog transforms the teacher directed monologue into an interactive process where students are encouraged to analyze synthesize and evaluate information
--The Knowledge Web

Camilla: Engaging the students in dialogue about the topic is a good idea because it gets the students really thinking about and processing the information they are being taught as opposed to just listening to the teacher lecture them on the topic.
-- Knowledge Web.</td></tr>
<tr><td>Con:
Peter: Some problems that might occur are that the teacher or discussion leader needs to be aware of the dynamics of the group which may be hard to do if their on a limited schedule and only spend limited time in the classroom.
--The Knowledge Web

Camilla: When the students do have a group discussion or multiple group discussions, whoever is facilitating or leading the discussion MUST have a complete understanding of the topic. If there are multiple groups, then 1 person in the group has to understand the topic fully and that may be difficult for the teacher to find. And if there is just a class discussion, then the teacher may not be able to get everyone to participate, depending on the class size.
--Knowledge Web.</td></tr>
</table>

Figure 1b. Round 1 Group Whiteboard

This initial experience identified several important issues, both theoretical and practical, that would need to be addressed before the next implementation round. First, the activity structure needed to more forcefully encourage interaction and discourage parallel play. Second, we needed to recalibrate our expectations for how norms of interaction would transfer and develop online. Third, from a cognitive apprenticeship perspective, the representations and activity structure needed to better scaffold the students' learning and problem solving (Collins, Brown, & Newman, 1989; Hmelo-Silver, in press). The activity structure and multiple workspaces were not integrated in a meaningful way that communicated an approach to learning and provided an impediment to the human facilitator trying to work online, which is a frequent challenge in developing CSCL environments (Dillenbourg, 2002). Thus, this initial experience demonstrated the need for distributing some of the facilitation onto the interface and activity structure (Steinkuehler et al, 2002).

ROUND 2: GETTING STUDENTS ENGAGED

For the next round, we redesigned and structured the activity to address the concerns mentioned above. Yet we still needed to embody a student-centered learning process that provided more milestones for the students' activity. First, we reconceived these phases of the activity and their milestones as timeframes rather than as deadlines to try to make this a continuous activity rather than one with discrete deadlines. We divided the activity into 12 discrete steps to help the students manage their time and effort as shown in the roadmap in Figure 2a. Second, the titles of the steps more clearly communicated what students might expect in each part of the PBL activity. In addition to better structuring the task, the task itself was simplified. Rather than having students redesign a lesson, they engaged in a collaborative conceptual analysis of two small minicases, chosen from a complete video case that contained 10 minicases. The prompts in the individual notebook were designed to help students focus on pertinent aspects of the case and to help them make decisions about what minicases they would analyze and the concepts they would explore in depth (Figure 2b). After the group analysis, students were required to design their own individual lessons incorporating what they learned from the analysis. The threaded discussion board was the place for students to (1) decide on the minicases they would analyze, (2) choose concepts to explore, and (3) make comments for a scribe chosen by the group to incorporate into the conceptual analysis in the whiteboard tool (Figure 2c). Again the whiteboard was supposed to be a shared context that provided a focus for discussion. The activity was designed to be completely online with initial individual analysis, joint group analysis of a section of the case (the "minicase") and then individual design of a lesson. This design overcame the parallel play problem—students posted and responded to each other's ideas (DelMarcelle & Derry, 2004; Hmelo-Silver & Chernobilsky, 2004). There was also a great deal of interaction—but this occurred entirely in the threaded discussion.

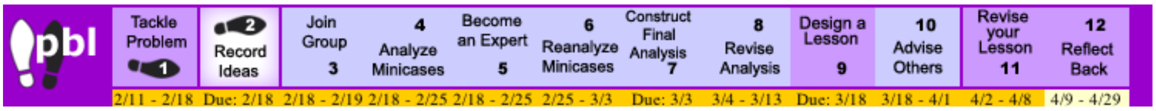

Figure 2a. Round 2: The road map

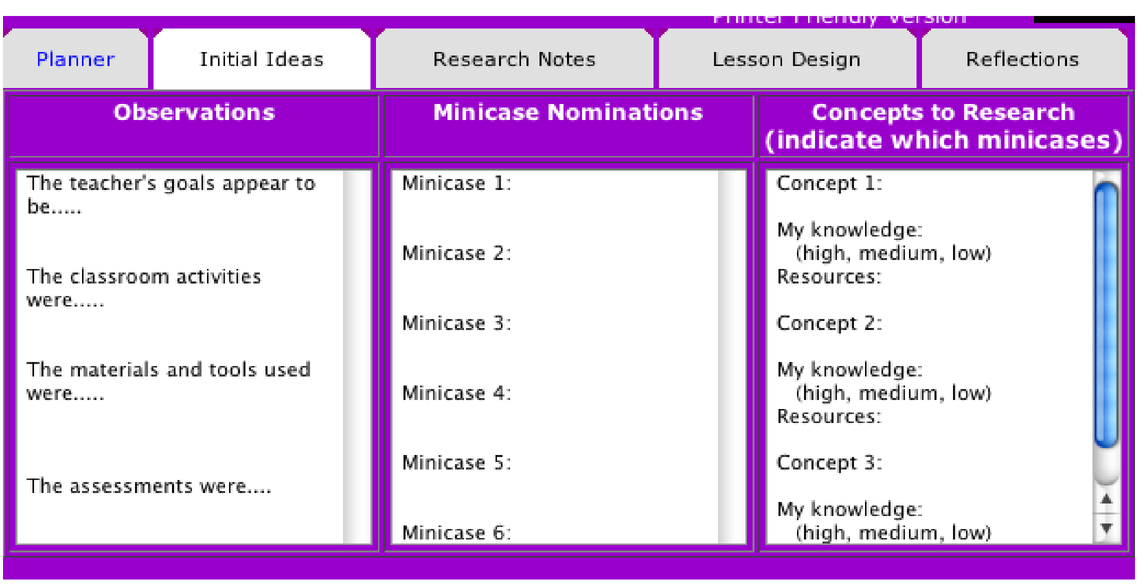

Figure 2b. Round 2 Individual Notebook

Reflecting on this implementation we identified two major problems with this design. First, the whiteboard itself did little to focus group discussion in productive ways. We had succeeded in getting students engaged in the activity but not always productively. Often their posts involved either elaborated conceptual discussion without strong connections to the case or alternatively, were very grounded in the case with superficial connections to conceptual ideas. For example, Figure 2c shows the students using a lot of vocabulary to describe what the teacher, Kyle, should be doing. They make some connections to the specifics of the case (Kyle controlling the discussion) but they do not provide evidence to back this up. Although the students exhibit a clear preference for a student-centered discussion, it is not clear how well they understand why this should enhance student learning. From a procedural standpoint, the roles that students needed to play in this activity were somewhat inauthentic and not optimal for learning. For example, one student had to be designated as the scribe to put up the entry for the entire group. Negotiation had to be conducted in the threaded discussion. This made it difficult to integrate the threaded discussion with the conceptual analysis on the whiteboard. The lack of integration made facilitation difficult. In the example above, the facilitator might have wanted to push students on their understanding of the concepts that they had mentioned but lack of integration made this difficult. This experience made it clear that the design had to provide representations that could support and guide anchored collaboration (Guzdial et al., 1997; Hmelo, Guzdial, & Turns, 1998; Suthers & Hundhausen, 2004). In anchored collaboration, discussion is "anchored" around the artifact being discussed—i.e., the students needed to be able to comment directly in the whiteboard, which was not possible in this implementation.

Second, the activity provided structure, albeit a complex one. The discussion was the major place where students worked, as this particular group posted 147 notes in 18 threads over six weeks but it offered no guidance to focus the students. Many posts were devoted to choosing the specific minicases to examine and deciding which concepts would be explored (DelMarcelle & Derry, 2004). The next round needed to address getting students beyond procedural issues and towards deep discussions that engaged students in wrestling with knowledge. In addition, the conceptual analysis was not clearly connected to the students' goal of designing an individual lesson, thus the activity structure needed to be more coherent.

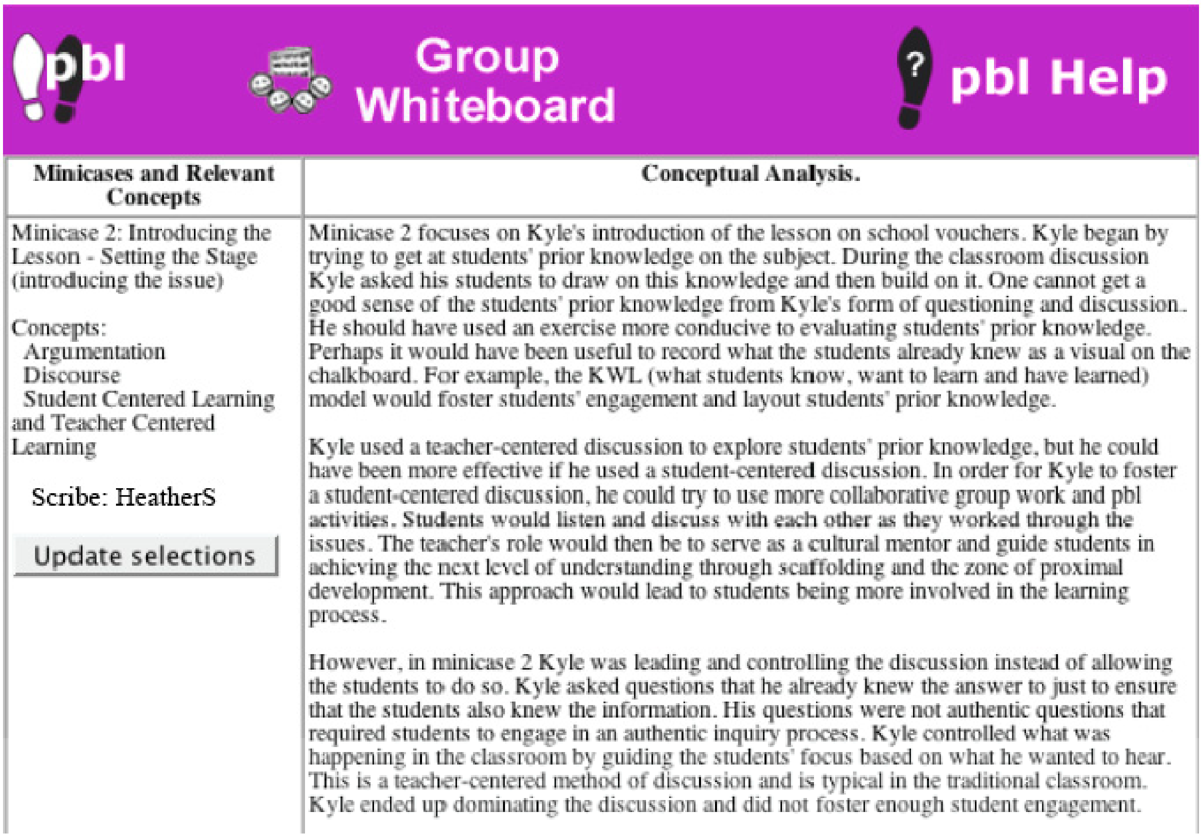

Figure 2c. Round 2 Group whiteboard

In addition to addressing the practical problems we identified during round two, we also developed theory about how students learn in complex knowledge domains. Derry (in press; Derry et al., this volume) argued that transfer of ideas from the classroom to future practice requires helping students develop representations that support complex forms of cognitive "meshing" among concepts, skills and perceptual visions of practice. We conceptualize both pre-professional learners and the practitioners as people who experience their environments through cognitive processes that are essentially perceptual in nature. These processes involve (1) perceiving situations in the environment, which activates complex cognitive patterns within individuals, and (2) responding to those perceived situations with understanding and actions, in ways that hopefully apply previously acquired course knowledge. It is important then to teach so that ideas, including concepts (e.g., attention, metacognition), and skills (e.g., scaffolding, reciprocal teaching) covered in our courses, are later assembled both to explain situations encountered in later professional practice, and to support planning and appropriate actions in those situations. This evolving theory started initially as a refinement of early ideas about PBL, cognitive flexibility theory (Spiro et al., 1988), and cognitive apprenticeship (Collins, Brown, & Newman, 1989) but became something quite different as we compared our intentions in design, the actual implementation of our first two rounds, and comparisons with the interactions that occurred in face-to-face discussions (Derry, in press; Hmelo-Silver, 2000; Chernobilsky, DaCosta, & Hmelo-Silver, 2004). We needed to support interactions that *meshed* ideas about the perceptual information from our instructional redesign problems with conceptual ideas about the learning sciences through both our whiteboard design and activity structure. We attempted to address all these issues in the next round of design.

ROUND 3: TOWARD MESHED INTERACTION

We made a number of changes for our third design round. First, we reduced the complexity of the activity structure, as the revised road map shows in figure 3a. This new activity structure also was more authentic than prior activities. Rather than focusing on a conceptual analysis task, we structured the problems to be either redesigns of the lesson in a video or adaptation of techniques shown in a video. Thus there was a clear problem for the students to work on. We also used a hybrid activity structure in which some of the activity occurred online but steps that required students to discuss procedural issues occurred face-to-face (e.g., deciding which concepts to explore). We very explicitly embedded the backward design process, developed by Wiggins and McTighe (1998) throughout the online activity beginning with the preanalysis recorded in the individual notebook (Figure 3b). This helped provide a structure for the activity as a whole and for the whiteboard and notebook tools in particular as it provided a principled model for instructional planning. In this approach, students began by identifying the big ideas worth knowing, considering what might be evidence of that understanding, and then planning instructional activities that would provide that evidence.

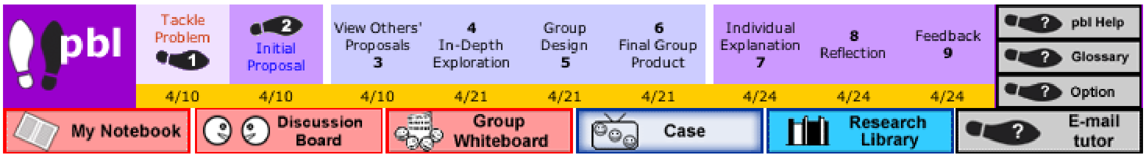

Figure 3a. Round 3 Road Map

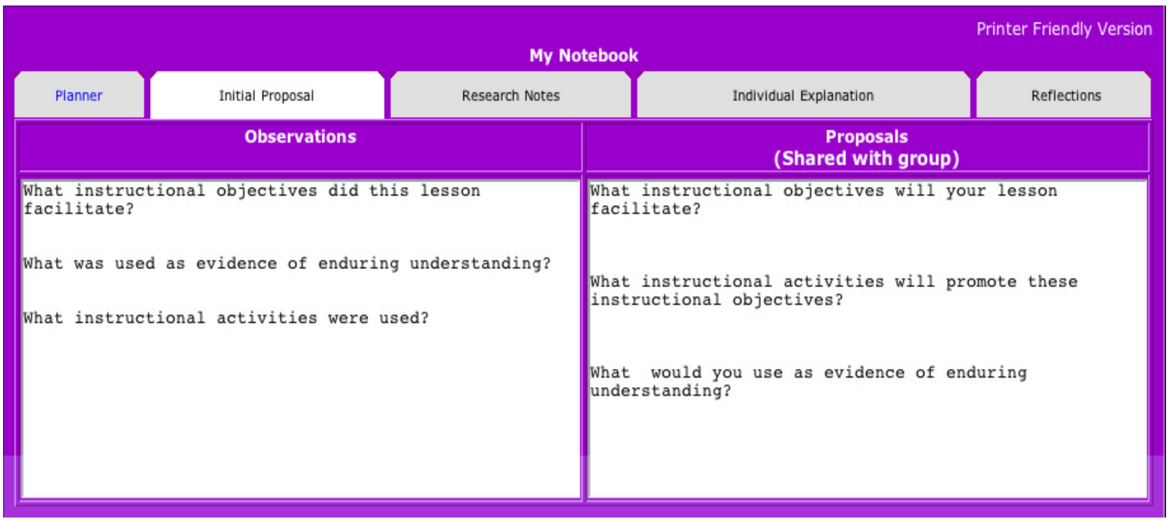

Figure 3b. Round 3 Individual Notebook Example

With mesh as a goal, we reflected back on prior implementations. Because the earlier activity structures and group whiteboard seemed to hinder complex discussion, we redesigned the group whiteboard to more seamlessly connect design and adaptation proposals to discussion spaces. In this round, the whiteboard included an integral discussion space as shown in Figure 3c. In the example shown here, students were using contrasting cases of lessons about static electricity. The students were told that the first teacher had attended a workshop given by the second teacher and, as a result, that he wanted to redesign his own lesson. In practice, students would post ideas or proposals for redesign and the board would automatically attach a comment space for each group member to reflect on, evaluate, and provide feedback on the proposal. This design addressed two critical issues. First, it clearly and effectively represented potential solutions to the problem along with the associated discussion of each solution. In prior implementations, solution ideas and the discussion of them quickly diverged. Second, these two spaces were physically connected allowing students and facilitators to easily interact with one another. In particular, this allowed the facilitator to help support perceptual-conceptual meshing by being able to ask questions that are anchored to the students' comments. After a student entered a proposal, each group member had a space to comment on that specific proposal. Not shown in Figure 3c is the facilitator's comment "Great discussion folks-- what is the psychological rationale for having students work on experiments? See Sally's comment below as well." As this example shows, the students were all able to post responses to this proposal for an activity as well as posing questions to the rest of the group ("What does everyone else think?"). In addition, although the software had the limitation of only being able to provide one comment on any proposal, this group developed norms to maintain all their comments in their response boxes. This design accomplished making the whiteboard the focus for negotiation. In this particular problem, which the students worked on for two weeks, there were 50 posts in the whiteboard and only 20 posts total in the discussion board, mostly for the purpose of sharing research. Students appeared to be engaged in productive ways as demonstrated by the number of posts and detailed analyses of student discourse (Chernobilsky et al, this volume). Over several semesters of using this learning environment design, students in the eSTEP environment demonstrated significant learning gains compared with students in a comparison group (Derry et al, this volume).

This design clearly accomplished the goal of creating interaction focused on the students' proposals for assessments and activities. What evidence then do we have that they are meshing the conceptual and perceptual ideas? In the proposal below, Maria talks in somewhat general terms about trying to apply a cognitive apprenticeship to design a learning activity, specifically using the notion of scaffolding as well as the need to apply what they learned to a real life situation. Carrie proposes the idea of a prediction sheet and then Maria, in her comments, talks a little more about the need to help structure the activity. Carrie jumps in at one point to ask about the connections to the video they watched. The group works together to clarify their understanding of what they saw in the video as well as to refine and specify an activity that might fit their notion of a cognitive apprenticeship, in particular, focusing on scaffolding and context. Sally later posts, in response to Carrie's ideas about experiments and adds the notion of deliberate practice to help the students learn inquiry skills:

> I think that it's a good idea, but I think them actually doing the experiment would be much more beneficial to the students. It would give them a way to critically think and plan out an experiment then test it out and see what works and what doesn't. Then they can modify it to make it work or work better. I think them having hands on experiments helps them really learn the concepts and helps them make connections to things they might not by just thinking about it. You may think something'll work, but when you try it you realize that you missed something or something is wrong….If they don't test them out they should be able to write something or explain to the class and teacher why they feel it would work and be able to answer questions about it… it! The teacher could walk around and give feedback throughout the experiment. In How People Learn it says that "learning is most effective when people engage in 'deliberate practice' that includes more active monitoring of one's learning experiences" (58-59) I think that hands on activities allow students to deliberately practice what they are learning and can be very beneficial to learning.

Elsewhere, Linda proposed that the teacher engage the class in concept learning and initially provides a fairly decontextualized description, concluding with "Blair Johnson should use this idea so that static electricity does not become an isolated concept in students minds that they will not be able to use. Finally, teachers should use concepts in "REAL LIFE SITUATIONS" as this has been shown to "increase chances of transfer, link ideas to prior knowledge, and decrease chances of misconceptions." Here Linda was meshing notions of concept learning with general advice to the teacher.

Proposal 6 by MariaM

Last edited: 04/05/2004

2 of 0 users. Included in Final Product

Proposal:
I think one way we can incorporate all these ideas into an instructional activity would be to break the class up into groups and have them discuss the concepts of static electricity. We could design a question and answer sheet that would help the students in "cognitive apprenticeship. In other words e need to facilitate or even initiate a discussion that would help the students to inter act and create a scaffolding. Once the teacher observes the students displaying the evidence of enduring understanding she can then implement fading and allow the students to act as the facilitators gaining knowledge be explaining to others what is not understood

Second and experiment could be designed for the groups and a prediction sheet should be handed out. Each student can then explain why he/she thinks their predictions will work and hw they will go about testing the materials. Each group should then present to the class
Why they chose the method that they did
What worked and what didn't
What were their misconceptions and what did they already know.

Lastly a real life scenario should be given to each student and they should be asked to apply the concepts they learned to this situation. For example why a person's hair sands on enc when static electricity is applied to the body. The students should e able to explain why this happens in concrete terms using the concepts they have explored during experimentation.

Research Findings:
http://stellar.wcer.wisc.edu//step/theories/TheoreticalPerspectives/SocioculturalTheory/CognitiveApprenticeship

Do you support the inclusion of this proposal in the final Group Product?
Yes No Vote

Comments by SallyA:
I see where Maria is coming from when she discusses the above! I feel that they are really good ways of handling the situation at hand ands I was thinking along similar lines when she talked about the real live scenario and the questions and answer sheet! I never thought of a prediction sheet, but now that she mentions it, it seems like a great idea! What else does everyone think?!

Comments by MariaM:
I think having the students design the experiment is a good idea however we are talking about Mr. Johnson's class. These students may not have enough knowledge to design an effective, thought provoking experiment. Having a discussion on how to test concepts might work, however we want them to learn about the components of electricity, (opposites attract, same charges repel) I think it would be difficult for them to design any activity when we are trying to get them to learn. Designing the activity is a part of structuring their abilities. We need to provide some structure in the initial fazes. However, we could ask them to design an experiment to test their findings as a step towards summative assessment.

Comments by CarrieM:
New comment: Maria, I know what you are talking about with the whole developing a experiment being a good idea to do but then again, in Etkina's class she did not have the groups design their own experiment – she gave them the task/experiment of the tape for them to work on in groups to determine which of the 3 hypotheses they came up with prior to the experiment where true in the end. So what I am wondering is are we saying we want Blair Johnson to have students develop their OWN experiment or use an experiment he assigns to them as Etkina did??? Either way, I think the experiments assist the learning process because it gets students to work with the material.

Old comment: I did not remember either, Patricia. I went back to the clips and watched the ones about the tape experiment. Etkina gave the introduction tot he experiment to the class as a whole and said: "Professor: Imagine… here it goes… imagine you can pull these tapes that are stuck to the table off the table… what do you think should happen, based on all your knowledge of electric processes, to these two tapes if you put them close to each other?" After that, the class has a discussion about what they thought would happen, and after the discussion came to a conclusion of 3 possible predictions about what the tape experiment would illustrate. Then the next clip showed them go into their groups and do the experiment themselves to figure out which one of their predictions were going to be true.

Figure 3c. Round 3 group whiteboard

These are just a few examples of many that could be used. We attribute part of the success in creating mesh to providing this anchored collaboration environment, in which students' (and the facilitator's) contributions and reflections are connected to authentic planning activities and the rich perceptual experiences the video cases afford. In addition, in this round, the facilitator became a full participant in the group work. Because of the specific place allocated for the comments on the white board, the group members respond to the facilitator's efforts at scaffolding learning. The group shown in these examples was particularly good at meshing their conceptual and perceptual ideas. But they also demonstrated some limitations in the system. They developed a norm of labeling their comments so they could keep track of their discussion as they labeled their comments as old and new. As groups engage in lengthy discussions, we need to keep the advantages of the integrated space but find a way to give them room to grow. Although there is still work to be done and variability among how groups use the whiteboard, we have constructed a whiteboard design that meets our initial practical goal of a providing a space for negotiation and our later theoretical goals of supporting conceptual-perceptual meshing.

DISCUSSION

This paper tells the story of the evolution of our design through hypothesis generation about what features would support the kinds of discussion we hoped to promote, implementation of the design, followed by critical analysis of interaction patterns. Our experience in designing for productive interaction led us from a focus on pragmatic issues of taking an effective instructional model and adapting it for online use to one of instantiating a theory of how people effectively learn from cases. We went from an under constrained environment to a very highly scripted version and found an appropriate middle ground that met our instructional and theoretical goals (Dillenbourg, 2002). As Dillenbourg notes, CSCL designs need to create activity structures that integrate disparate individual and collaborative activity phases as well as face-to-face and computer mediated communication. Such designs need to consider landmarks for managing time and the important role of the facilitator. There are risks in such designs, several of which were experienced in the evolution of eSTEP. In particular, our first two rounds of design disturbed the kind of natural interactions that needed to occur. In Round 1, the interface did not make it clear how the whiteboard and the threaded discussion were related so these tools failed to shape the collaboration in productive ways. In Round 2, breakdowns occurred when the activity structure did not help the students come to consensus on their choices of what concepts and minicases to focus on. In addition, the complexity of the activity structure in Round 2 may have served to increase the cognitive load of the group members.

In the tradition of design experiments, our goals were twofold: to develop and refine theories about learning and to “engineer” the means to support that learning (Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003). Our iterative design process was a reflexive one in which our instructional theory both informed and evolved from our system design. In the beginning, having never implemented a collaborative activity in an online environment, it was expected that we would make a few mistakes. Simply learning the constraints and affordances of the technology and how students would interact with it was an initial goal. As we began to see how we could effectively use technology to support PBL, we refined important components of the instructional environment and we began to better understand the connection among the activity structure, the group whiteboard, and the students’ collaborative knowledge construction. We developed a theory that connects three critical components of our instructional environment and describes how they contribute to effective learning that promotes transfer to professional practice. The first component, the learning sciences or conceptual component, was the foundation that we began with. In the beginning, the primary goal was to teach students the learning sciences and how they can be used to inform instruction. To this end, we utilized face-to-face problem-based learning activities that required students to analyze and design instruction. The second component is the planning or design component. We wanted students to learn the connection between instructional theory and design, but we also wanted them to develop design skills that fluently blended the two. As we moved activities online and began to experiment with video cases, we began to understand the need for students to ground their conceptual and design knowledge in knowledge of actual classroom practice. Unlike paper cases, however, video provides an unparalleled perceptual experience. The latest round of eSTEP attempts to authentically and meaningful connect these components of the instructional environment. Our theory suggests that the rich conceptual and perceptual meshing that the eSTEP affords will help teachers transfer their learning sciences knowledge to their future teaching practice.

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The Shape of the Elephant: Scope and Membership of the CSCL Community

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Abstract. This paper discusses the character of the CSCL research community. While members of the community often feel they have authoritative perceptions of the nature of the community, these perceptions often differ. This paper is an attempt to look empirically at the CSCL community as constituted by leadership in the CSCL conferences. Data are included about who, historically, has published in the CSCL conferences and how those people are distributed across academic disciplines and regions of the world. In addition, the relationship between CSCL and the learning sciences is explored.

Keywords: Citation analysis, bibliometrics, sociology of science, computer-supported collaborative learning, learning sciences, communities of practice.

An old parable tells of three blind men trying to describe an elephant; one describes the ropy tail, another describes the leg like a trunk of a tree, and a third describes the snake-like trunk. Disagreement ensued. All three were locally correct, but all three were wrong in their incomplete view of the whole.

Research fields can be like the elephant. Although participants in the communities might believe they have a comprehensive view of the shape of the whole community, perceptions are shaped heavily by personal perspective. This can yield conflicts, when agendas or definitions for a research community are set. In this paper, we attempt to describe some of the patterns of participation in the CSCL research community based on empirical data derived from the CSCL conference proceedings from 1995 to 2002.

INTRODUCTION: THE SHAPE OF RESEARCH COMMUNITIES

What is a scientific community? How can we explore or define one? The most literal definition would be a community, that is a group of people engaged in shared activities towards overlapping goals, doing science, or systematically modeling and understanding the world. In the stereotypical ideal, the scientific community (only one) is full of people who uncover truths and generally build on what is known about the world to answer questions that are unknown.

Unfortunately, this vision of a research community suggests a much tidier world than the one we live in. First of all, there are many scientific communities, not just one monolithic one. Our “truths” are subject to negotiation and reinterpretation, based not only on data, personal knowledge, and methodological inclinations, but also biases, politics, and personal interests. (Kuhn, 1962; Latour, 1987) We are limited by our humanity, and since our ability to understand and apply science is filtered through our own human capabilities, perhaps this is a good thing. Scientific communities are messy.

A further problem in asking about the nature of scientific communities is that the participants do not see them clearly from a distant point of view; they live them. Debates can get quite heated when evidence suggests ones’ own interpretation of the world may be wrong, whether it is an interpretation of some scientific domain or more personally an intepretation of one’s own community and practices. People may simply reject ideas that require radical interpretation of how things are (Chinn & Brewer, 1993).

Still, it is a sign of a healthy community that is open to questioning itself, its motives, goals, and definitions, even among scientists. As scientific communities progress, they make obsolete their prior interpretations of the world, and this sometimes requires reframing the endeavor at hand. Just because the mission statement or definition of a field might change is not a reason to abandon the endeavor entirely. Such definitions can become a flag that can help rally communities towards common goals.

Science is as science does. In prior work on defining scientific communities (Hoadley, 2004), I argued that there are five core features that define research communities: scope and goals, theoretical commitments, epistemology, methods, and history. Each of these features leaves, to some extent, a trace in the literature of the field. In this paper, I examine the CSCL literature represented by the CSCL conferences, and then attempt to use this information to propose some characteristics of the CSCL community to date, while still recognizing that the CSCL community is a living organism that changes every minute. While there are a number of other venues for CSCL related work that exist, such as the CRIWG, the problems of source selection would be considerable if opened up to include additional sources. Rather than expand the scope of this study to first, determine, and second, analyze, all CSCL-relevant conferences, this analysis focuses primarily on the CSCL conference itself.

With the "moving target" in mind, I hope to shed some light on a few questions about the CSCL community as represented by the CSCL conference. First of all, who participates? What disciplines or geographic regions do they come from? Do they stay in the community over time? Secondly, what is the relationship between the CSCL community and the community termed "the learning sciences"?

BIBLIOMETRIC ANALYSIS

In this section, I undertake a bibliometric analysis of the field of CSCL as represented by the CSCL conference series. Bibliometrics may be used to answer basic questions about scholarly communication, such as who publishes in a field and how much; what are the connections in the field as indicated by variables such as coauthorship or citation; and who uses a particular research literature for what purposes (Borgman & Furner, 2002). The present analysis builds on a bibliometric analysis of the fields of learning sciences and instructional systems design through six publication outlets during the time from 1991 to 2001 (Kirby, Hoadley, & Carr-Chellman, in press). While these prior analyses looked at cross-field citations and geographic distribution of coauthorship, the present analysis focuses instead upon who participates in the CSCL community, where they come from, and the relationship between other outlets in the learning sciences and the CSCL conference.

Data sources and coding

Our team collected and coded ten years of six publications judged (perhaps imperfectly) to be representative of the learning sciences and of the instructional systems design community. Three of these publications were used in the present analysis. From the learning sciences, the group collected and coded the two conference series and the journal now sponsored by the International Society for the Learning Sciences, namely the *Journal of the Learning Sciences* (begun in 1991), the proceedings of the *International Conference for the Learning Sciences* (or *ICLS*, also started in 1991), and the proceedings of the *Computer Supported Collaborative Learning* conference (begun in 1995). Additionally, the *CSCL* series is analysed through the January 2002 conference, in part due to the fact that the conference was originally scheduled for late 2001. Note that this analysis does not include the proceedings of *EuroCSCL 2001*, a conference that was explicitly regional in its focus. This omission is primarily due to logistical issues.

While bibliographic statistics are often taken for granted in the era of bibliographic databases, our data collection involved enormous effort. Partly due to the recent beginning of the various learning sciences publication venues, partly due to the variety of publishers of the works, it took nearly a year to assemble a complete set of materials. Original hard copies of the works were obtained, and the title pages and back matter for each article were photocopied. The title page information was entered into a database, including article citations and author affiliation information. We then coded author affiliations where provided geographically, by country, state or province (for Canada, the United Kingdom, and the United States), and city. Authors' names were manually standardized. In some cases, missing affiliation information was omitted from the database (i.e., we did not attempt to uncover more affiliation than what was published, so for instance if an author address did not contain departmental affiliation, no attempt was made to find out what department the author was from).

Where provided, departmental affiliations were coded into one of twelve categories (see Table 1). Authors were coded into as many categories as applied, either because they changed departmental affiliations, or because they had multiple affiliations.

Table 1: Disciplinary coding for departmental affiliations

Psych:	Psychology or educational psychology (including human development)
Education:	Education, not including educational psychology, cognitive science, or learning sciences (includes Pedagogy, Curriculum and Instruction, Instructional Design, Educational Technology, Science/Math Education, etc.)
CompSci:	Computer science, computer engineering, human-computer interaction
Info:	Information sciences, information design, informatics, or library science
MediaComm:	Media, communications, mass communication
Linguistics:	Linguistics
Soc:	Sociology or political science
Anthro:	Anthropology
CogSci:	Cognitive science (only when this phrase explicitly used)
LearningSci:	Learning sciences (only when this phrase explicitly used)
Business:	Business and management (including organizational science)
Other:	Departmental affiliation that does not match any of the above

In addition to the authorship data, conference websites were used to identify program and steering committee members for the CSCL conferences from 1995 to 2003, this time including the EuroCSCL conference (under the presumption that while participation in the conference might be regionally focused, editorial governance was not). Where websites had disappeared, the Internet archive was used. Unlike the authors, these conference organizers were tracked down using the best available current information, including Google searches.

Stability of community leadership

Our first analysis concerns the stability of the CSCL conference community core. Have people participated in the community for years, or is it a “revolving door” which doesn’t really represent a stable group of individuals at all? We begin with an analysis of the program and steering committees. Overall, 226 people served on either program or steering committees, 86 served on at least one steering committee, and 192 served on the program committees. Of the 226 people on these committees, 92 participated in more than one role in the conference over the years. Seventeen people served as either conference chair or program chair. They were counted automatically as members of the steering committee.

Of the steering committee members, 57 (roughly 2/3) served in another conference capacity over the years (either another steering committee or a program committee.) Of the 29 people who served only as a steering committee member once, all but a few (<5) were either at the host institution or local to the hosting institution for the conference. This seems to indicate a relatively high degree of stability at the core of the conference organizing community, although the location does clearly influence conference leadership.

Among program committee members, 84 (roughly 45%) served the conference multiple times (either on another program committee or as a steering committee member). Approximately 12 of the people who only served the conference once were local to the host institution, meaning in the same or nearby cities (although this number is larger if Scandinavians are treated as local to each other). Thus, there were a much larger number of program committee members who served the conference only once as a program committee member.

Among both program and steering committee members, 70 served the conference over multiple years. The average timespan of service for these multi-year individuals was 3.6 years. Looking through the data, few of these people “dropped out” along the way. The maximum possible average based on the starting dates of each individual is 4.9 years, indicating that those who were involved with more than one conference tended to stay involved over a long period of time. 34 people served in 3 or more conference roles (see Table 2).

Table 2: Program or steering committee members participating in three or more roles

Name		Participation years			Number of roles played			
First	Last	From	To	Span	Total	Chair	Steer.	Pgm.
Michael	Baker	1999	2003	4	3	0	0	3
Amy	Bruckman	2002	2003	1	4	0	2	2
Tom	Carey	1995	1997	2	3	0	2	1
Allan	Collins	1997	2002	5	3	0	0	3
Pierre	Dillenbourg	1999	2003	4	6	1	1	4
Lone	Dirckinck-Holmfeld	1997	2003	6	3	0	1	2
Yrjö	Engeström	1997	2003	6	4	0	0	4
Anneke	Eurelings	1999	2001	2	3	0	2	1
Gerhard	Fischer	1995	2002	7	4	1	1	2
Shelley	Goldman	1995	1999	4	3	1	1	1
Louis	Gomez	1997	2002	5	3	0	0	3
Kai	Hakkarainen	2001	2003	2	6	1	2	3
Päivi	Häkkinen	2001	2003	2	3	0	1	2
Rogers	Hall	1997	1999	2	3	1	0	2
Christopher	Hoadley	1999	2002	3	3	0	1	2
Ulrich	Hoppe	1999	2003	4	6	1	1	4
Janet	Kolodner	1995	2003	8	3	0	1	2
Timothy	Koschmann	1995	2003	8	11	2	4	5
Erno	Lehtinen	1999	2003	4	3	0	0	3
Naomi	Miyake	1995	2003	8	7	1	0	6
Anders	Mørch	2002	2003	1	4	0	2	2
Hiroaki	Ogata	2001	2003	2	4	0	1	3
Gary	Olson	1995	1999	4	3	0	0	3
Claire	O'Malley	1997	2003	6	5	0	1	4
Roy	Pea	1995	2003	8	5	1	1	3
Rolf	Plötzner	2001	2003	2	3	0	1	2
Mitchel	Resnick	1995	1999	4	3	0	0	3
Jeremy	Roschelle	1995	2003	8	7	1	1	5
Gerry	Stahl	2002	2003	1	4	1	1	2
Manasori	Sugimoto	2002	2003	1	3	0	1	2
Daniel	Suthers	1999	2003	4	6	0	3	3
Felisa	Verdejo	2001	2003	2	4	0	2	2
Barbara	Wasson	2001	2003	2	5	1	2	2
Earl	Woodruff	1995	2002	7	4	1	1	2

Disciplinary representation

The authors of CSCL represent a variety of academic disciplines. Although not all of the 721 unique authors provided enough information to code their departmental affiliation, 549 authors did on at least one CSCL paper. 99 authors were affiliated with more than one field, either due to multiple affiliations on a single paper, or due to affiliations that differed over time. 47 authors had affiliations coded as "Other," ranging from science, math, or engineering disciplines to health, systems sciences, literature, and so on. Of the Education category, many had affiliations to educational technology in particular.

This analysis of disciplines is unfortunately incomplete. It fails to indicate, for instance, the discipline(s) in which authors were trained, and it is likely to under-represent multidisciplinarity or cross-disciplinarity that exists within academic departments. For space reasons if nothing else, authors tend not to include a detailed disciplinary pedigree in the affiliation information in their papers. Likewise, it does not necessarily accurately represent the intellectual affiliations of the authors when a nonstandard affiliation was provided (for instance, an acronym specifying a laboratory rather than a traditional academic department). Finally, these disciplinary codes mask differences within disciplines. For instance, a psychotherapist and a cognitive neurologist might both be coded as the same discipline if they both belonged to a psychology department.

Table 3: Distribution of authors across academic disciplines

Discipline	count
Psych	64
Education	334
CompSci	81
Info	39
MediaComm	42
Linguistics	1
Soc	0
Anthro	23
CogSci	2
LearningSci	56
Business	2
Other	47

Geographic representation

Where do CSCL conference presenters and leadership come from? Is CSCL a truly international conference? Beginning with the steering and program committees, the answer is a qualified yes. Of the 226 people identified, 129 (57%) are from North America (US, Canada, Mexico), 81 (36%) are from Europe, 8 (4%) are from Asia, 6 (3%) from Australia-Oceania, and 2 (1%) from South America. The geographic distribution is somewhat different for the 34 active participants in Table 2, where we see 17 (50%) from North America, 14 (41%) from Europe, and 3 (9%) from Asia.

The authorship shows a similarly international pattern. Of the 343 papers analyzed, 258 were coauthored and 24 of these (9%) were collaborations of authors from multiple countries. These international collaborations are listed below in Table 4. If each authorship event is taken separately (i.e., we analyze each author of each paper in the proceedings), we find 900 authorship events. Not all authors identified affiliations and locations (862 of 900), but when they did, authorship was spread across 24 countries, listed below. Here, North America represents 64% of authorship, Europe 26%, Asia 8%, Australia-Oceania 2%, and South America 1%. See Table 5. Obviously, these results would emphasize European participation more if the EuroCSCL 2001 had been included as well.

Table 4: Cross-national collaborations (coauthorship)

Countries (in alphabetical order)	Number of papers
Australia and Brazil	1
Australia and Canada	1
Australia and USA	1
Brazil, Japan, and USA	1
Canada and Japan	1
Canada and New Zealand	1
Canada and Taiwan	1
Canada and USA	2
Denmark and USA	1
Finland and USA	1
France and Norway	1
Germany, UK, and USA	2
Israel and USA	1
Italy and Norway	1
Italy, Japan, and Netherlands	1
Japan and UK	1
Mexico and USA	2
Sweden and USA	1
Switzerland and USA	1
UK and USA	2

Overlap with learning sciences

The issue of whether there is a distinct CSCL community apart from a learning sciences community has been a matter of some contention. In the section that follows, I examine first the relationship between leadership in the two areas, then the relationship between publishing authors in the venues examined previously.

First, there is considerable overlap between the leadership of the two groups. Because data were not collected on the leadership of the learning sciences from the literature (e.g. program and steering committees of the ICLS conference, editorial and review board members of the *Journal of the Learning Sciences*), here I compare the leadership of the International Society of the Learning Sciences and leadership in the CSCL conferences. ISLS has had three boards of directors (an interim board, a founding board, and the board elected in Spring 2004.) Of the 34 people listed in Table 2, 13 have been on the board of directors of ISLS. Looking in the other direction, a majority of the members of each board of directors of ISLS appear in Table 2: 11 of 18 for the interim board, 7 of 12 for the founding board, and 7 of 12 for the Spring 2004 board. Each of the four presidents of ISLS appears in Table 2. The overlap in leadership is even larger if we include all CSCL program and steering committee members: 16 of 18 for the interim board, 10 of 12 for the founding board, and 10 of 12 for the Spring 2004 board.

If the leadership of CSCL overlaps with the learning sciences, do the pools of authors overlap? Of the 721 unique authors, 261 (36%) were also authors of works in either the International Conference of the Learning Sciences or the *Journal of the Learning Sciences.* Of these overlapping authors, 12 did not provide locations, leaving 249 locatable crossover authors. 219 were from the United States and 14 were from Canada. The remaining crossover authors were from Finland (4), Germany (9), Israel (2), Japan (3), the Netherlands (2), Sweden (5), Switzerland (1), and the United Kingdom (8). Put another way, of the 579 North American (US, Canada, Mexico) authors in CSCL, 233 (40%) also published in venues titled "learning sciences," while non-North American authors were much less likely to publish in these venues (16 of 130, or 12%). These data indicate that while there has been an overlap between the two learning sciences publications and CSCL, it was primarily a North American phenomenon as of January 2002.

Table 5: Authorship events by country

Country/Region	Count	Percentage
China	3	0.35%
Israel	9	1.04%
Italy	4	0.46%
Japan	46	5.34%
Singapore	2	0.23%
Taiwan	3	0.35%
Asia	67	7.77%
Australia	11	1.28%
New Zealand	3	0.35%
Australia-Oceania	14	1.62%
Denmark	12	1.39%
Finland	29	3.36%
France	6	0.70%
Germany	57	6.61%
Greece	9	1.04%
Ireland	3	0.35%
Netherlands	19	2.20%
Norway	22	2.55%
Spain	6	0.70%
Sweden	12	1.39%
Switzerland	6	0.70%
United Kingdom	43	4.99%
Europe	224	25.99%
Canada	61	7.08%
Mexico	5	0.58%
USA	486	56.38%
North America	552	64.04%
Brazil	5	0.58%
South America	5	0.58%
Total	862	100.00%

DISCUSSION

This analysis provides several important insights about the CSCL community, as represented in the authorship and publishing of the CSCL conference. First of all, CSCL is, as purported, a multidisciplinary field. This suggests that some of the potential conflicts identified in Hoadley (2004) may apply to CSCL as it matures, including theoretical, methodological, and epistemological conflicts. A second finding is that CSCL represents an extremely wide geographic diversity. While some regions (such as South America and Australia-Oceania) are not heavily represented in this dataset, the breadth of participation suggests that further support of international participation would meet an international interest in the field. Connection to regional conferences in these areas might be one approach to solve this problem. Third, the data suggest that, for North Americans CSCL is an outgrowth of the learning sciences, while for non-North Americans, it is not. This points out that how CSCL is interpreted and practiced from a disciplinary sense may be highly contingent on local disciplinary contexts.

The US National Academy of Sciences recently released a report highlighting the importance of interdisciplinary research, and the difficulties such research faces (Committee on Facilitating Interdisciplinary Research, 2005). The report identifies four drivers of interdisciplinary research: "the inherent complexity of nature and society, the desire to explore problems and questions that are not confined to a single discipline, the need to solve societal problems, and the power of new technologies." (Committee on Facilitating Interdisciplinary Research, 2005, p. 2) Certainly, many in the field of CSCL would agree that all four drivers apply to this field. CSCL studies complex interactions between natural (psychological, sociological) phenomena and social goals, works on problems that cross social sciences and computer science, is driven by complex societal problems such as education, and is directly impacted by the rapidly shifting technological tools available to us. The report suggests barriers that come with this interdisciplinarity. Interdisciplinary work requires both interdisciplinary collaboration and exchange. It also requires changing some of the organizational and social structures that are supported by disciplines. Interdisciplinarity requires extra effort on the part of a wide variety of stakeholders, ranging from funding organizations to academic institutions to governmental or policymakers to students. This cross-disciplinary effort includes working towards mutual understanding of disciplinary methods, languages, and cultures.

The CSCL community faces additional challenges because it is, generally, an international phenomenon as well. Researchers in the field therefore must not only cross disciplinary methods, languages, and cultures, but must also cross national or regional methods, languages, and cultures. It is all the more surprising that the CSCL community has become as international as the results suggest in the short span of its existence. Such internationalism is a testament to not only the interest produced by important problems of CSCL, but also to the deliberate efforts of those in the community and the community leadership to permit and promote international activity. Obviously, the community builds on the strength of its North Atlantic ties, but should make deliberate efforts to extend this participation to other regions; the presence of the CSCL conference in Asia is an important step in this direction.

What can we do with these results? If CSCL is to succeed in the future, it will need to overcome the challenges associated with interdisciplinary research, and to continue surmounting challenges posed by a global reach. On a personal level, this might include making connections to those in other disciplines and building relationships with other researchers across national boundaries. But, more subtly, these results also suggest that members of the community must approach governance, reviewing, and other evaluative tasks with full knowledge that while each person might imagine that they have a relatively complete picture of the community, this is actually quite unlikely. The debate over whether CSCL is related to the Learning Sciences is an example of where the presumption that one knows one's own community can be fallacious.

What will the future of the CSCL field look like? While future-gazing is by nature speculative, I can predict that, based on prior stability of community leadership by solid scholars from multiple domains, the community will continue to build on a successful tradition of valuable scholarship. Many questions remain, however. Will the field come to represent a discipline unto itself, or will it continue to be a relatively porous grouping that draws on people from multiple disciplines? As the community continues to embrace new audiences from additional geographic regions, it is likely to encounter more culture-clashes from different regional manifestations of disciplinary norms. However, this might provide not only a new burden of building common ground, but tremendous fuel for cross-disciplinary fertilization of ideas. The integration of learning sciences concepts and community into non-North American research communities is another likely source of cross-pollination. CSCL seems poised to bridge these gaps via the hundreds of researchers who have previously attended and presented at both CSCL and ICLS conferences.

As CSCL reaches its tenth birthday, it is important to realize that we are the blind men feeling our own elephant. Important discourse must take place on the characteristics that make CSCL a desirable research community. Given the huge barriers that are already being surmounted—intercontinental travel; cross-disciplinary discussion, authorship, and review; and continuity of the community's leadership—it is clear that CSCL provides a special and valuable venue for researchers whose work could instead be limited to their disciplines or localities. As we explore together our theoretical commitments, epistemologies, methods, and goals, we can come to better understand our history—and our future.

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Building Bridges within Learning Communities through Ontologies and "Thematic Objects"

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Abstract. Communication through artefacts, in the sense of objects (co-)constructed by learners, is a well known mechanism in synchronous shared workspace environments. In this article, we explore the potential of extending this principle to heterogeneous, anonymous and asynchronous learner communities by drawing on existing work, e.g. in the areas of "social navigation" and recommender systems. A new ingredient is the description and provision of "thematic objects" embedded in a task/activity context. Design principles and available technologies are discussed and an example implementation in a European project is presented from the perspective of technology design and development.

Keywords: Artefact-centred community support, social navigation, content-awareness

INTRODUCTION

Shared workspaces with visual objects enrich human-human communication by opening a new channel: *communication through the artefact*. When jointly creating and manipulating artefacts, the co-learners' language based interaction is complemented by an external medium providing inherent constraints. Whereas language utterances rely on individual interpretation "in the head", actions on the object level have directly observable results and consequences that may constraint future actions. Communication through the artefact is a basic principle used in a variety of shared workspace environments in CSCW and CSCL. The typical activities are editing, brainstorming, (co-)construction and (co-)design. Several authors such as Hoppe and Plötzner (1999) or Suthers and Hundhausen (2003) have characterised communicative and cognitive functions of interactively co-constructing and using shared representations. The latter distinguish the following three functions: initiating negotiations of meaning, serving as a representational proxy for purposes of gestural deixis and providing a foundation for implicitly shared awareness (group memory).

A shared workspace environment may support domain unspecific representations such as concept maps and/or hand written notes, but it may also support more specific, semantically enriched representations such as system dynamics or Petri Nets. Our experience is based on a multi-representational tool called Cool Modes (Pinkwart, 2003) in which a whole spectrum of representations is supported. In spite of the common outsiders' view of CSCL technology being essentially used in remote learning scenarios, shared workspace environments are often used in face-to-face settings as an additional communication channel together with natural communication and, of course, as a structured medium with external memory function. The typical usage scenarios involve smaller groups of 2-5 participants over a time span ranging from some minutes to two hours. Both limitations in group size and in time are inherently linked to the relatively tight coupling of activities between group members. It is usually assumed that there is a high degree of continuous awareness between the session participants and the cooperative activity would not allow for much parallel work in other completely unrelated activity threads (i.e., even "private" activities are usually related to the co-constructive group task). A balanced ratio between one's own active contributions as compared to the activity overhead that stems from continuous awareness (perception) is one of the main factors that limit group size, whereas time is limited by the ability to continuously concentrate on a coherent task without being able to accommodate for individual breaks or timeouts. In the following we will constructively explore possibilities to relax these constraints in time and group size while still maintaining essential features, hopefully benefits, of "communication through the artefact".

What cannot be expected to be transferred from the tightly coupled situation is the support for deictic references in (real time) communication. Yet, the external memory function can be redefined from – metaphorically speaking – short term to long term memory support. In classroom usage of collaborative modelling environments such as Cool Modes, we have experienced situations in which the sharing mechanism has been used to transfer information from small groups to the whole class, e.g. to display and discuss group results in the public. Yet, in this public situation, input is usually restricted to the moderator or teacher and the responsible group. Also, this is typically not "late re-use" but "immediate re-use". In a recent study, Katrin

Gassner compared a number collaborative discussion and argumentation environments, among other features, with respect to their support for later re-use and found a clear deficit in this respect. This brought us to considering (and implementing) combinations of synchronous co-constructive environments with indexing and retrieval mechanisms (Hoppe & Gassner, 2002). Although this implied a relaxation of time constraints, it was not explicitly related to differences in group scale.

With respect to group size, there is a qualitative difference between groups in which members know (of) each other and share context in terms of location, curricular content and institutional features (staff, teachers) and anonymous groups which may share an interest on the content level without sharing much context. Direct or indirect (i.e. mediated) content orientated social relationships have been supported and studied with anonymous groups under the notion of "social navigation" (Höök, Munro & Benyon, 2002; Dourish & Chalmers, 1994). Our intention to support the interoperability between different group scales can also be seen as an attempt to bridge the gap between direct and indirect social navigation. For CSCL purposes, we propose a specific version of social navigation that relies on the notion of "thematic objects". Thematic objects are understood as learning objects enriched with metadata which classify the object both within an ontology and in terms of social relations.

This approach of *social navigation based on thematic objects* or *thematic social navigation* is focused on the following point: It is a basic purpose of social navigation to support users in finding other users with whom to interact in some beneficial way. We assume that thematically classified learning objects can be used as indicators for "shared interests". In a learning community, such shared interests are an essential condition for mutually enriching interactions between learners. The learners could even interact indirectly through the inspection and re-use of objects of shared interest without necessarily having a person-to-person communication. A comparable approach for assessing shared interests in scientific communities has recently been presented by Francq & Delchambre (2005) using document indexing and retrieval techniques. In our approach, both the ontological classification of objects as well as the association of metadata from the activity context (user, tools) allows us to extend the search to classes of similar learning objects. This kind of content awareness functionality is built into a collaborative learning environment. This environment combines access to a repository for asynchronous sharing with synchronous shared workspace functionality.

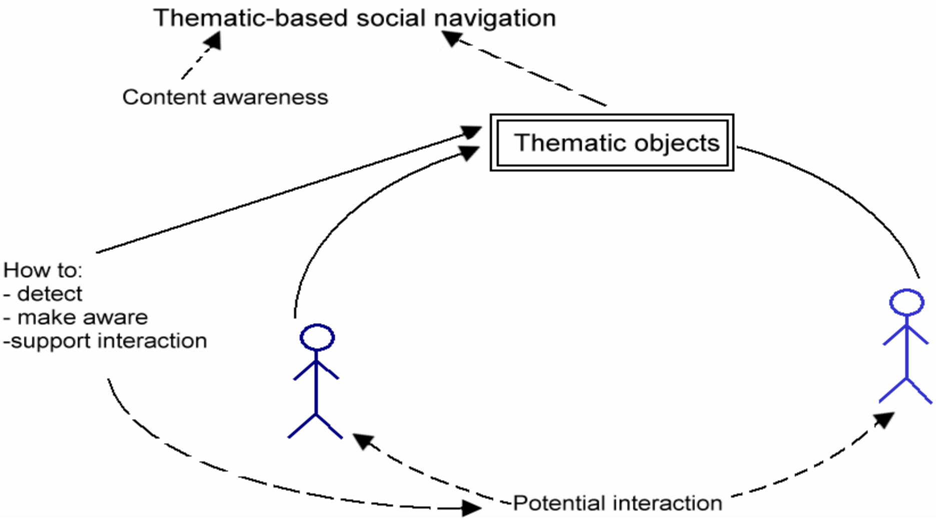

Figure 1 Social navigation through thematic objects

BASIC CONCEPTS AND SUPPORTING TECHNOLOGIES

This section intends to identify the key concepts and to put them in relation to the social navigation and artefact based communication principles that were outlined in the introduction.

Dealing with documents and document handling, the notion of *metadata* (i.e., data describing data) is of obvious importance. Related problems are the often needed manual generation, which users may conceive as an annoying task they tend to avoid (Wickens, 1992). Other critical aspects are related to standardisation and interoperability. A frequently chosen technique to overcome the interoperability concerns are *ontologies*. In the sense of Gruber (1993), an ontology is an "explicit specification of a conceptualisation". Other definitions are more operational and conceive an ontology as a conceptualisation of a domain into a human-understandable, but machine-readable format consisting of entities, attributes, relationships, and axioms (Guarino & Giaretta, 1995). One benefit of ontologies, as compared to other less structured and formal approaches, is their suitability for classical AI and knowledge representation techniques (Uschold & Grüninger, 1996). Another advantage of ontologies is that they allow for adding a new abstraction level upon the metadata layer. This draws out links between entities that were apparently unrelated, thus extending the querying vocabulary for the users. Furthermore, the ontology can be used for guiding the users by sorting out this larger amount of possible queries and by providing mechanisms for deriving new knowledge. Finally, an ontology may facilitate navigation through repositories by taking profit from the available context information.

Apart from the more descriptive approaches of ontologies and related taxonomy based techniques, there is a variety of technologies that deal with the usage and processing of data and metadata. These range from classical search approaches with Boolean logics up to complex *information retrieval* methods, which are able to deal with vagueness of queries and uncertainty about data (e.g., Fuhr, 2001). For our aims, the field of information retrieval thus offers important inputs through the algorithms it provides. Yet, classic information retrieval methods do not consider user specific and task related information and can therefore not serve as a basis for our implementation.

Research on *recommender systems* is probably the most closely related and therefore most relevant area for our approach. Similar to information retrieval, recommender systems aim at providing users with relevant documents. Yet, the principal approach differs in that recommender systems rely on (user provided) ratings of documents, which are either used directly for recommendation of the rated document, or indirectly to infer ratings for similar documents (Resnick & Varian, 1997). A frequently applied method in the field of recommender systems is *collaborative filtering* (see Konstan & Riedl, 2002). This algorithm essentially follows three steps:

1. search for users with a profile similar to the current user
2. search documents that these users rated positively
3. order these found documents using relevance criteria of the current user

Obviously, this algorithm is closely related to the ideas of social navigation through thematic objects as expressed in the introduction – in a sense, it is orthogonal, as our approach first searches for documents and then, in a second step, finds users. The collaborative filtering method has proven to be effective, but has several inherent problems. These include the *cold start problem* ("how to give recommendations for newly introduced items?") and the early-rater problem which describes the problems arising from new documents (Sarwar et al., 1998). Several mechanisms to overcome the cold start problem have been proposed. Some of these are based on the idea of community membership (Glance, Arregui & Dardenne, 1998). Here, new users assign themselves to communities, and the system takes other members of that community as reference. The general consideration of community aspects in recommender systems was also used to take into account the fact that people in a community potentially share topics of interest – accepting that people may be members of several communities with different shared topics. Another approach to overcome the cold start problem of recommender systems has been proposed by Middleton et al. (2002). They investigate the synergies evolving from an integration of recommender systems with ontologies, the latter being used to determine initial user profiles. However, their approach still relies on explicit and manual user assessment of documents.

The driving ideas for this paper differ from all the listed concepts in that they do require neither explicit nor implicit document assessment but instead make use of automatically available activity context for indexing and retrieval. One of the case studies contained in this paper presents how functions can even be embedded in the tool that provides the task context. Technical aspects of this solution are explained in Pinkwart et al. (2004).

In our approach, the activity context links interest-related aspects to object-bound features and can thus be conceived as a connection of user- and document-related metadata. The aims are similar to those of recommender systems, and in particular to the idea of collaborative filtering. Yet, we are able to exploit a richer source of information due to the additional context dimension. The context of a user activity is characterised by the types objects worked on as well as by the types of activities performed. The repository we suggest provides an adequate framework for storing, retrieving and re-using groups' results and by-products, and the portal we propose supplies new ways of finding context information. Finally, as an added-value, the portal makes it easier for users to access the community, their results and a number of helpful facilities such as semantic navigation or enhanced searching. The next sections of this paper show how this information can be used to enhance re-use options of documents in a community, and support the exchange of communities through documents. The latter aspect illustrates the idea of the seeding of new collaboration options through social navigation by thematic objects in the sense as motivated in the introduction.

SUPPORTING A COMMUNITY OF SCIENCE LEARNERS

The example application scenarios used in this paper are all related to the ongoing European project COLDEX ("Collaborative Learning and Distributed Experimentation"). COLDEX takes up issues and current challenges in the area of technology support for collaborative learning in science and technology with a special focus on learning based on both local and remote experimentation. Within this project, learning experiences and results based on local experimentation in personalised local communities are considered to be a subject of exchange in a broader community, including long-distance communication. In this sense, the aim is to provide and explore exchange mechanisms between local communities in Europe. Here, direct communication channels, e.g., by e-mailing between learners, are not the primary and original goal. As motivated, we focus on artefact based exchange mechanisms – not excluding their potential function as triggers for direct communication, however. The central medium for exchange is the “Learning Object Repository” (LOR) which is described in the next section of this paper. It provides both group and community navigation tools as well as mechanisms to detect similarities of interests in terms of the produced objects or artefacts. This is a special case of the general ideas related to “social navigation and community support” introduced above.

One of the tools used in COLDEX is Cool Modes (Pinkwart, 2003), a multi-representational framework to enable collaborative modelling. The Cool Modes tool supports synchronous cooperation in a shared workspace environment with coupled objects. Specific types of objects and relations can be defined as domain-dependent plug-ins. Most of these plug-ins offer graph-based representations, but also handwriting annotations are provided.

Users of the LOR system can take multiple different roles which represent the different group scale they work in: *local group members* belong to the same (local) face-to-face learning group; *Cool Modes users* create models within the tool environment and upload them to the repository. *Community members* of a certain scientific domain may be interested in Cool Modes models. *Individual learners* can be members of these groups, but also external visitors interested in the contents of the repository because of its relation to scientific topics.

Groupware support for challenge-based learning

The COLDEX project aims at supporting learning and experimentation with open-ended challenges for which no ready-made solutions can be found in a textbook. The themes are mostly inspired by “exploring space” and include examples such as lunar cartography, the programming of robot vehicles, or growing plants in space. Our idea of *challenge-based learning* (or henceforth ChBL) is thus a special form of problem-based learning (cf. e.g., Barrows & Tamblyn, 1980; Koschmann et al., 2001) characterised by targeting non-standard, typically extracurricular, problems in a research orientated learning mode. It aims at familiarising students with adopting a scientific attitude and approach. Here, the advantage of a centralised learning object is the potentially highly contextualised and diverging background of the thematic learning objects. This complexity is a necessary ingredient for a meaningful and rich collection of data and metadata.

Research and practice in CSCL shares a basic experience with other groupware applications in that using group orientated software tools puts additional demands on the users. I.e., the use of group or community orientated tools comes with an additional cost (in terms of additional coordination and interaction efforts). Thus, from a motivational point of view, there should be a clear benefit in using these tools. For example, if the explanation of an experiment is standard content of textbooks, it is quite unlikely that learners would engage in time consuming communications with people around the world to understand the experiment. On the other hand, if the problems dealt with are non-standard and of really open-ended and exploratory nature, there is an obvious incentive to engage in such an exchange. This is the basic argument for concentrating on challenge-based learning as an educational approach. So, the specific pedagogical approach of “building bridges within learning communities” (not only within the COLDEX project) can be characterised by the three basic elements:

- extending “communication through artefacts” from local to global learning communities,
- contextualising community information bases with thematic and task-orientated parameters, and
- using challenge-based learning as an overall educational design principle.

These themes have an innovative potential, both from a scientific point of view (in CSCL and Community Information Systems) as well as for educational practice.

Examples challenges and thematic exploration

One of the COLDEX learning scenarios is “robot in a maze” (Jansen et al., 2004). It has two characteristic activity modes: (1) the construction of a new maze as a challenge to other learning groups, and (2) the definition of a robot strategy to escape from (hopefully any) maze in the form of *situation-action rules*. For example, a rule for the given situation “free in front and on the left, but blocked on the right side” could be: “go forward”. One of the most obvious strategies for guiding a robot out of a maze is “wall following” which can be challenges by putting islands in the maze. The Cool Modes system supports both maze construction and the definition of rule sets. The corresponding learning objects (of type *maze* or *rule set*) can be put in the LOR. A rule set can additionally be executed with a Lego robot in a physical maze.

The two different aspects of the described scenario foster a special kind of competition between the maze constructors and the students that program their robots. The users can categorize different classes of mazes (with or without islands, single or multiple exits, exits at the edge or within a maze), and other users can find different strategies to solve arbitrary mazes of these classes. This allows for a mixture of competitive and collaborative group work patterns. Using this scenario, the role of the repository is evident, as users can retrieve more classes of rule sets or mazes which they then try to compete with there own mazes or strategies. Further usages of the repository (beyond simple searches for mazes and rule sets, or analysis of the contained data) arise if descriptions and keywords are considered. For example, a user can add the information about his maze class, or can state that his rule set is "the best" and succeeded in all tested mazes.

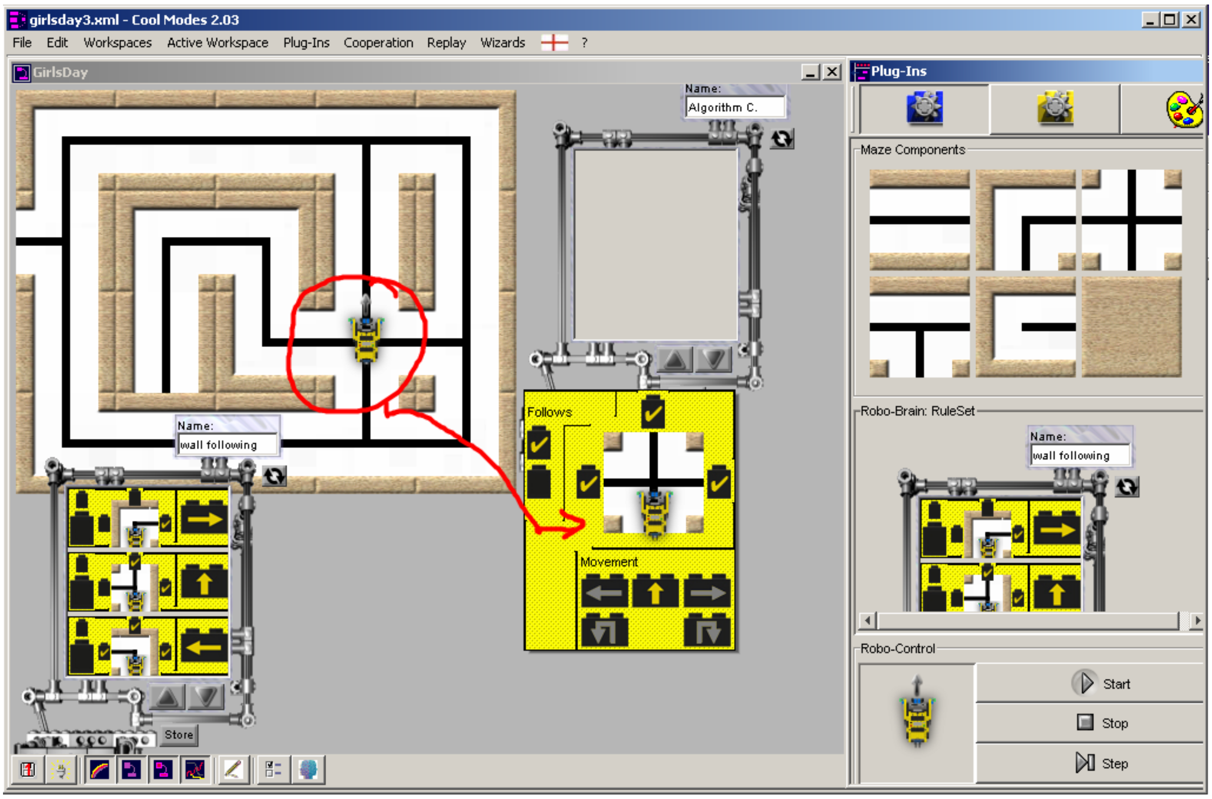

Figure 2 Maze scenario: simulation in the modelling environment

Another example of a scenario is "lunar cartography" (Hoeksema et al., 2004). Here, the activity flow spans from taking pictures of the moon to calculating measures such as diameters or crater heights by using an interactive tool embedded in Cool Modes. Using the LOR, users can exchange different (annotated and contextualised) moon pictures to cover different phases of the moon, in order to compare the same crater shown in different views taken at various sites. The repository can also serve as a platform to extend and enhance a collection of moon objects with measurements.

Costs and benefits

The costs of using the repository for retrieval issues are the following: just on their own, users have to elaborate solutions in a potentially complex and highly demanding way, there are no ready made solutions available. In contrast, the user can collaborate, search the repository for helpful examples, share partial solutions with the community and thus compose one possible solution for the problem at hand. The additional time effort, of course a cost aspect, faces the benefit to minimise manual indexing. Similar trade-off situations have been discussed for information pooling scenarios with database tasks (Cress & Hesse, 2004).

Again, a big problem concerning repositories is again the "cold start problem": There will be no benefit in spite of the required efforts before a critical mass of reasonable retrievable thematic objects is reached. Of course students should be informed about the future benefit to motivate their efforts. Often, it is also possible to provide an initial set of learning objects from previous experiences or even constructed by a teacher. A similar problem occurs with user profiles in a growing group of users/learners. Therefore the initialising of user groups and thus an initial set of user information (partly provided through tedious manual input) should be facilitated as fast as possible.

Non-standard challenge-based learning activities require higher "investment" of creativity and involve a higher risk of failure. They typically come with less context information and scaffolding than, for example, in common practice scenarios in schools or undergraduate academic settings. On the other hand, they are highly rewarding in case of success and they can strongly benefit from exchange in large learner communities, including asynchronous settings and initially anonymous groups.

	Cost	Benefit
Finding resources	Time effort	Information pool
Creating documents	Additional time and work effort	Learning by doing
Contextualisation	(Automatic generation: system cost)	User benefits from context information
Indexing	(Automatic indexing: implementation cost)	Large range of possible queries to serve different information needs
Session preparation	Start server, join session	Collaboration (+ log data, i.e. more context information)
Storing documents in a repository	Additional time effort: uploading and manual input of additional metadata	Information pool
Re-use of documents	Retrieval and adaptation	Learning from other users' experiences, getting different views of the same challenge (ideally: understand other users' approaches)
Extracurricular nature of repository usage	More time effort to research, to find interesting thematic objects	Learning not only facts, but also acquiring scientific working mode
Challenge-based learning	Potentially highly complex tasks	High user motivation due to the non-standard nature of topics, opportunity to learn from experience rather than from textbooks
Learning community	Not knowing everybody personally	Connection of peers with similar interests

Table 1 Costs and benefits for ChBL

THE LOR

In order to describe, integrate, and retrieve information created by a learning community with a variety of resources, our approach is to define a learning object repository (LOR) with an explicit conceptual model, an ontology, capturing community work processes and resources (Verdejo et al., 2003). The ontology we employ consists of the following top level concepts:

- *Learning Objects* (LOs), the core data entities stored in the LOR. Their structure includes references to associated resources, tools, learning design parameters and other contextual educational information, and (in some cases) information about input and output formats.
- *Actions*, which allow the classification of user actions according to several categories (e.g., Activity Theory or models of scientific experimentation activities).
- *Goals*, which specify the purpose of certain actions.
- *Complementary* metadata information, encapsulating domain or scenario parameters.

The expressive power of a learning object management system is a function of its vocabulary, but also of its description format and the abstraction levels enabled by its definition. In our case, this vocabulary includes standard (IMS-LOM) as well as non-standard metadata slots, as learning communities may often want to define their own descriptions to suit their needs.

The LOR integrates data and artefacts created from heterogeneous resources. Artefacts, in this sense, are the products created by the learners using certain tools. It is possible to upload results in arbitrary file format, such as images (e.g., from telescopes) or multimedia documents created with commercial tools. These objects are uploaded through a web interface. As for content keywords, such objects have to be indexed manually whereas user and group information can be added by the web environment. Using specific COLDEX tools such as the Cool Modes system the upload is directly embedded in the tool environment and allows for generating more metadata automatically. These "metadata generated from tool context" include not only user information (from the login and an internal user profile) but also information about the course context (represented as metadata in hand-outs and working instructions) and information about object types and operations known in the tool environment. E.g., in the maze application it is possible to distinguish a maze design from a rule set by the object types. A maze document can be easily distinguished from a lunar cartography calculation by the different plug-ins (and by the different object types).

There is general mechanism for interfacing between the LOR and single tools, which is essentially enabled by mapping schemes between the LOR ontology and the tool dependent information. The LOR also includes a mechanism to create object descriptions from contextual community information derived from the conceptual model, to further enrich an object description with social data in a transparent way. A by-product of this is the ability to support personalisation for specific sub-communities, as these define different application contexts. Once a new LO type is defined, the LOR will be able to store it, providing adequate metadata values taken from the community portal or the tool context.

The LOR is a service to store LOs and enable their retrieval. Users can define new object types, and add or delete objects of any of the types available. The mechanism to define a new object type consists of declaring the list of metadata to be added to this LO type (apart from the standard set, which is automatically added to every type). This operation is performed once to make the system aware of the new LO type existence. Once we have a set of object types, any user can add or delete objects, either through a web portal, which provides to the user a direct access to the LOs, organised in workspaces (Verdejo et al., 2004), or directly through specially enhanced tools in the original task environment (Pinkwart et al., 2004).

To this point, we have described the mechanism for storing and indexing results of learning activities. Next we have to define corresponding mechanisms for navigation, retrieval, re-use and information sharing. The following subsections will explain principles of navigation support based on group context, semantic navigation, and navigation and exchange through thematic objects. A common point in these subsections is the notion of *contextualisation*. The central idea discussed in this paper is the use of learning objects as a means for initiating asynchronous artefact-centred communication. Here, contexts are used in two different aspects: first, *learning object contexts* serve as (meta-)data resources upon which explicit retrieval functions and navigation strategies operate. Second, *task and tool contexts* are exploited in implicit, similarity based retrieval operations: without leaving the current activity context and tool environment, users can, e.g., ask for similar documents or objects (i.e., similar to those they are working on) and can retrieve peers with supposedly similar interest, namely the authors of these documents. The found "similar" documents can, again, be directly accessed and manipulated within the tool context.

Semantic Navigation

Semantic navigation is enabled by the ontology, which establishes a new abstraction level upon that provided by raw metadata. A benefit of this higher level of abstraction is bringing out links between entities that were apparently unrelated. For instance, a particular tool could be discovered to be related to a given project or to another tool by means of the ontology. Thus, two different groups could be found to be related by the fact that they work on projects which share a common challenge or because they have participated in activities which required using common tools.

The importance of this new level does not rely only on permitting new or more elaborated queries but also on adding the concepts represented by these queries to the user's working vocabulary. For example, a user can discover an association between two learning objects which were linked because they have one of their authors in common. These queries allow users to think in terms of different similarity variants: document based, person based, and task based.

The ontology consists of entities and relationships, but it also has inference rules. Rules allow for deriving new information from existing knowledge. Thus, for instance, a rule could state that every project needs a challenge, that whenever a new Learning Object is created, it is linked to the service which was used to make it or that users belonging to a group are considered to be developing the group's current project. New connections open new ways of walking through the LOR. The ontology makes it possible to navigate them by viewing these links at a higher abstraction level, that is, rather like relations between concepts than metadata annotating objects.

Finally, the portal brings forth context information, which enables new knowledge to be derived, such as the current activity being carried out within the project a group is developing or the tool they have selected for solving a particular task. Rules, again, apply to this knowledge to derive meaningful relations or facts, like offering that group this particular tool whenever a similar task is to be done.

Navigation support based on context and thematic objects

Users can either access the LOR through the web interface or through one of the available tools. In the first case, the web interface would present the metadata for a user-selected learning object together with the possible search categories, with values automatically filled according to the selected LO and its context. This object description is then taken as a query, allowing the user to edit or include fields (thus, adding constraints) or delete them (i.e., relaxing existing constraints). The results of these specifications define the kind of object the user wants to search. Then, the LOR searching mechanism will be triggered, and the results will be presented. If necessary, the user would be able to iteratively refine this search.

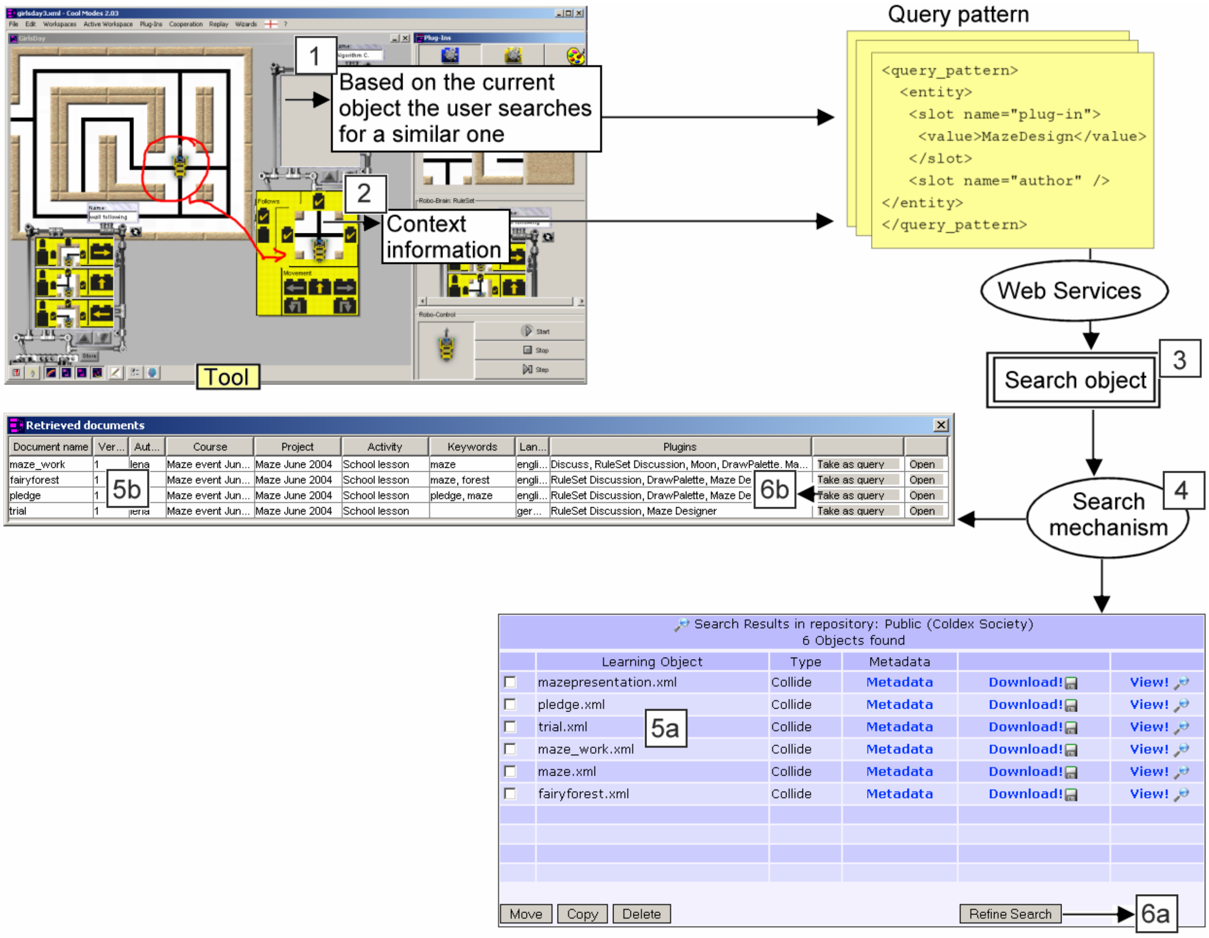

Figure 3 Searching LOs from a tool (Cool Modes) using query patterns

Figure 3 illustrates how thematic learning objects can serve as a source for finding "similar" documents that resemble the user's current task context: from within the modelling environment Cool Modes (here, used with a maze plug-in again), the user can initiate (without further parameter specification!) a LOR query for "related objects", whose implementation is based on the context of the current learning object and the ontology structure. The results of this query (i.e., the list of candidate objects) is mirrored back to the user, who can then either refine his search, or access one of the proposed documents *directly from within his current environment*.

This lookup mechanism for objects is "associative" in the sense that it enables the use of prototypical objects as a starting point for query generation. The user does not have to learn any query language in order to make use of the LOR. Based on this core functionality, we have implemented a number of search and retrieval mechanisms that work on the archive. The advanced mechanisms exploit the context of the current task of the user: together with the content of an object, the metadata about the tool, the user(s), and the current task (which may be associated to documents that have a history and, e.g., originate from the repository) constitutes thematic objects in the sense as described in the introduction of this paper.

Technically, the implementation relies on query patterns, which can be conceived as query masks generating concrete queries through filtering processes. There are two ways to define these, either using the ontology querying language or (in a more simple manner) through a combination of metadata. The latter is mainly offered through web services and permits establishing a link between the LOR and a number of previously known external tools. It would be initiated on demand of an external tool. A tool can define a query pattern library (Pinkwart et al., 2004), which allows the specification of particular search strategies for target objects. Some pieces of information needed for searches can be taken from the task context and thus be automatically provided by the tool itself at the moment an instance of the query is generated. For the example case of Cool Modes, the generated metadata currently includes, e.g., the employed modelling language, the user and his collaborators, and inferred educational parameters as well as relations to previous document versions - further slots are under development. This process is illustrated in figure 3 with an example using Cool Modes and goes as follows: first, the user would ask for LOs similar to his current one (step 1 in figure 3). An appropriate query pattern would be extracted from the library, and serve the purpose of generating a concrete query based on the user's current context and the strategy encapsulated in the pattern (step 2 in figure 3). Then, a "search object" (labelled

3 in the figure) would be built to trigger the search process (step 4 in figure 3). The rest of the procedure can either follow the steps already explained for portal-initiated search, or lead back directly to the tool and allow direct access to the LO (steps 5a/b and 6a/b).

With this document navigation based on thematic objects and their similarity, even more advanced usage scenarios are possible: based on a simple relation between users and the documents they have used, an extension of the similarity measure between documents to the associated users enables finding peers or groups of similar interest and, iterating this process, to realise social navigation based on the documents contained in the archive. For the user, this process breaks down to the simple question of "is there someone who is doing similar things to what I am working on?" The possibility of a system-side answer to this question is indeed a valuable point if one aims at fostering learning communities and their exchange.

Both ways, from the portal or by the tool, meet at a common point before triggering the actual search: an intermediate "search object" is generated, which includes the sought after properties for the target LO as well as relevant context values. The search object's content is either directly gathered from the portal context, as in the first case, or supplied by the tools, through a data exchange process, which, in turn, can be completed with contextual information. Once the search object has been built, the searching can be run, which would produce a result set. The process can be iterated and the user can participate in refining its results by changing values or adding constraints.

CONCLUSIONS AND OUTLOOK

So far we have explored and developed mechanisms to use learning objects in context as mediators for community interactions. These mechanisms are designed to support the sharing of ideas in open-ended and ill-defined problem domains. I.e., the expected benefit lies in improved problem solving performance facing the given challenge. The COLDEX environment is fully implemented and demonstrates the feasibility of the general approach, and particularly the Cool Modes system exemplifies the possibility of using tool information for contextualised indexing and retrieval. This, as such, is an added value regarding community support functionality. As one of the reviewers has correctly pointed out: this is a logical value added, not necessarily a psychological one. Indeed, the psychological validity of the described mechanisms has still to be studied beyond functional test of our system implementation.

The initial motivation for (re-)using objects in the community database can also be viewed from a sustainability perspective: what would long term effects look like? We assume that, under certain conditions, the development of social relations might gain a dynamics of its own beyond the sharing of thematic objects. This could in turn have an impact on the content level: the stimulation of social relations might foster certain types of innovation and even the definition of new challenges in the learning community! The investigation of this effect within the community will be one issue for the future research. Another open research issue is the following: Similar to "feedthrough mechanisms" in synchronous collaboration with direct manipulation, the artefacts that mediate the communication in our approach may be used as message containers through embedded annotations which "let the object speak" like a message in a bottle (e.g., a handwritten comment "whoever re-uses this model, may contact me for a further exchange"). This is possible and it would add a direct communication channel to the asynchronous exchange.

We believe that it is worth investigating the aspects of the enabling mechanism and the sustainability effects on an empirical level. Research on sustainability effects will typically require statistical types of analysis. Such types of long term analyses need data about a community using systems of the types we presented in this paper. For these purposes, we are currently developing (and using continuously in all our university lectures) an integrated web based learning support system (Pinkwart et al., 2005) that allows for a variety of evaluation methods, including "mixed mode social network analyses" (Wasserman & Faust 1994). On the evaluation level, we are also discussing pathways to analyse "hybrid networks" (ontology terms and persons), both in context of the LOR and the accompanying web portal. Applying this concept as a real time social network analysis for group reflection may also have interesting effects on the enabling mechanism.

ACKNOWLEDGMENTS

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A New Role for Computer-Mediated Communication in Engaging Teacher Learning within Informal Professional Communities

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Abstract. Computer-mediated communication (CMC) implementations, in particular among teachers, have not lived up to public expectations. This study examines some reasons for this and outlines a conceptual and methodological framework for characterizing the engagement of experienced and novice teachers in informal network-based professional learning communities. I postulate sustainability to positively correlate with what I term "CMC engagement." This study addresses three key research questions: (1) What properties constitute CMC engagement in professional learning e-communities? (2) Why do some CMC groups sustain themselves, whereas others do not? (3) How might the communicative structures of network-based CMC enhance or constrain the development of their e-communities, and in turn, pertain to CMC engagement? I argue that both the dialogicality of utterances (Bakhtin, 1986) and the use of texts as "thinking device[s]" for generating new meanings (Lotman, 1990; Wertsch, 1991) are essential for engaging practitioners' professional life. Using both qualitative and quantitative methods, longitudinal discursive data from public teacher email lists are subject to microgenetic, discourse, and ethnographic analyses, resulting in a novel taxonomy of e-communities and a characterization of CMC engagement. The findings provide a new formulation for sustainable learning in CMC-based professional teaching and learning environments, in both informal and formal settings.

Keywords: Computer-Mediated Communication (CMC), Engagement, Teacher Learning, Informal Professional Communities

INTRODUCTION

According to a recent report of the National Commission on Teaching and America's Future (2003), one-third of new teachers leave teaching within their first three years, and one half within their first five. Given the current fiscal and accreditation constraints in teacher education, any hope of meeting the national challenge of providing two million highly qualified beginning public schools' teachers by 2009, while also improving teacher retention by at least 50 percent by 2006, would appear to be unobtainable. Amid this crisis, education reform advocates have increasing hopes for incorporating information and communication technology when reforming teacher learning via collective professional e-communities (e.g., Riel & Fulton, 2001).

However, the outcomes of this to date have varied widely and are yet to live up to public expectations (e.g., Wade & Fauske, 2004). The literature identifies two general areas that compromise the rich possibilities of computer-mediated communication (CMC) for professional e-learning: (1) online discourse lacks depth (e.g., Putnam & Borko, 2000); and (2) teachers are reticent to use networked peer communication (e.g., Zhao & Rop, 2001). It follows from this that the current claims for the contribution of CMC might be exaggerated.

This study examines some reasons for this and outlines a conceptual and methodological framework for characterizing the engagement of experienced and novice teachers in informal network-based professional learning communities.

This study has important implications for improving networked communities of teacher learning in three significant areas. One, it provides a formulation for larger-scale explorations, the results informing both policy-makers and practitioners in their designing more cost-effective and sustainable models of professional development. Two, my project provides an alternative to existing professional development approaches. And, three, this study increases awareness and provides the details of shared professional language or discourse in analyzing educational practice, therefore filling a void in the American context (e.g., Lampert, 2000). My analysis will inform proactive ways in which teaching and learning may provide more professionally and intellectually rewarding experiences (e.g., Cochran-Smith, 2003; Nieto, 2003), while simultaneously acculturating, attracting, and retaining new and experienced teachers in classroom practice (e.g., NCTAF, 2003).

LITERATURE REVIEW

The CMC literature affirms the importance of technology in teacher education reform. It also highlights the need for robust theory and methodology to inform practice and significant longitudinal study to assess the effectiveness of such a strategy (e.g., Gunawardena et al., 1997).

Technology affects all our lives, and its ubiquitous use in education clearly has the potential to change the future of education (e.g., Tyack & Cuban, 2004). In particular, networked communication itself has proven a viable tool for mediating teacher education reform, including three frequently stated CMC goals: (1) information sharing, (2) fostering professional development; and (3) community building (e.g., Berge & Collins, 1998). Developed in the 1960s, CMC involves the exchange of text messages across time and space via networked computers, such as online chatrooms and electronic mail. However, its dynamic temporal-spatial parameters constrain as much as they facilitate conditions for creative communicative action.

Various methods have sought to characterize CMC interaction. But despite calls for examining the quality of interaction (e.g., Cazden, 2001), CMC research has remained focused upon structural and discursive content analyses (e.g., Fahy et al., 2001). Such research is useful. However, it fails to explain *how* discursive functions may account for CMC engagement. This is significant, given that CMC engagement involves genuine interchange, going well beyond simply the transmission of information.

High-level, in-depth online discourse is rare in educational settings (e.g., Nystrand, 1997) and CMC infrastructure alone cannot ensure engaging experience. Most studies have covered relatively short time frames, from week-long conferences (e.g., Gunawardena et al., 1997) to course-duration bases (e.g., Fahy et al., 2001), but rarely have they been conducted over significantly longer periods, or with larger self-motivated public communities.

The current study addresses all these issues and provides a coherent communicative theory and model of analysis that considers the CMC parameters that both facilitate and constrain high level CMC engagement as an alternative method for connecting teachers to professional and intellectual e-communities.

CENTRAL THESIS, ARGUMENT, AND RESEARCH QUESTIONS

The central thesis of this study postulates that "sustainability" positively correlates with CMC engagement. “Sustainability” has been considered an important goal of educational reform (e.g., Cole, 1996) and professional development (e.g., Franke et al., 1998), but little is known of its correlates.

"Engagement" is considered a crucial inquiry within a learning community among teachers and educators (e.g., Cochran-Smith, 2003) and will here refer to “genuine” forms of communication that goes beyond simple transmission-like exchange, as characterized by three principal dimensions: (1) how utterances are integrated and used for creating new meanings or “dialogicality and functionality,” (2) how utterances/texts are evaluated and elaborated for formulating new ideas or “exploration,” and (3) the development of overall threads, topics and participant activity or “structural characteristic.” Each is operationalized by further indicators.

I argue that by examining the ways in which our voices and utterances are integrated and used to comprehend and control communicative action for generating new meanings involve going beyond mere transmission of information and addressing CMC sustainability. This provides a key foundation for our understanding of sustainable CMC communities in engaging in quality dialogue and thinking.

Against this background, I address the following three key research questions: (1) What properties constitute CMC engagement in professional learning e-communities? (2) Why do some CMC groups sustain themselves, whereas others do not? (3) How might the communicative structures of network-based CMC enhance or constrain the development of their e-communities, and in turn, pertain to CMC engagement in general?

THEORETICAL PERSPECTIVES

Conceptually grounded in semiotic and discourse theories, the study's theoretical framework has its roots in sociocultural perspectives (e.g., Vygotsky, 1986; Wertsch, 1991) and communities of practice (e.g., Wenger, 1998). Specifically, my argument is grounded in two critical notions. First, I employ Bakhtin's and Wertsch's dialogicality of utterances, which refers to the ways we make meaning through engaging and responding to voices and utterances (see also Nystrand, 1997; Cazden, 2001). Second, I draw on Lotman's (1990) theory of using texts as "thinking device[s]" for creating new meanings. Both these theoretical perspectives emphasize the dialogic language use underlying my key claims for CMC engagement.

RESEARCH DESIGN AND METHODS

This study is both descriptive and analytical, employing mixed qualitative and quantitative methods. The qualitative aspects comprise microgenetic (e.g., Wertsch, 1991) and discourse analyses (e.g., Gee, 1999) for investigating the discursive practice of CMC engagement. Ethnographic (e.g., Carspecken, 1996; Hymes, 1986) and sociolinguistic perspectives (e.g., Briggs, 1986) are used to analyze communicative action, interview, and subjective interpretations informing the implicit norms conditioning the social reality of e-communities. Quantitative inquiry employs post hoc analysis and comparisons to determine the relationships between interview responses, coding components, and e-community categories.

Following institutional human subject research guidelines, research data are collected from multiple sources (i.e., text transcripts, interviews, and field notes) via participant observation.

DATA COLLECTION AND ANALYSIS

A total of approximately 1,300 messages comprising 80,000 lines of naturally occurring text message threads have been collected from experienced and novice teachers communicating via six contrasting public education email lists over two years. Email lists were chosen for their public access, levels of communicative activity, national and state representativeness, discipline, and representation of experienced and novice populations. Each text message is coded for levels of engagement (e.g., "dialogic CMC engagement" or "univocal informative exchange"), and prototypes are selected for in-depth analyses according to both micro- and macro-level coding categories. The unit of analysis is the episode or thread, including a minimal unit of individual message turn or utterance level. Inter-rater reliability check is undertaken.

Preliminary analysis has shed new light on three major issues: (1) different forms of professional teacher e-communities, (2) the emergence of engaging e-communities, and (3) characterization of these engaging teacher discourse e-communities.

First, two distinct forms of e-communities have been identified as distinguishable by speech genres (details below). "High engagement" communities are characterized by their "dialogic CMC engagement" level, resembling genuine conversation, scaffolding thinking and socialization through integrating discourse. In contrast, and more common, are "low engagement" communities which show a more transmission-like communication, predominately comprised of "univocal information exchange." For example, two of six target email lists are "high engagement" communities (41 percent message threads are "dialogic CMC engagement"), the remaining four are "low engagement" communities (91 percent, "univocal information exchange").

Second, "high engagement" communities would appear to emerge in the presence of extensive chains of communication, during the progressive development of topic levels as may be represented by multi-layered tree diagrams of twenty topic levels or more. Such multiple topic levels are sustained by both high, and mixed engagement levels of "dialogic CMC engagement" and "univocal information exchange." Furthermore, a high "dialogic CMC engagement" level correlates with deeper reflection on pedagogy. Conversely, the "low engagement" communities display a limited development of topics (ranging from one to five levels) and are frequently characterized by single topic level discourse threads with a few mixed engagement levels. It follows from this that high and mixed engagement levels afford a greater capacity for sustaining the long chains of communication more typical of "high engagement" communities.

Third, the characteristics of speech genres reveal quite different levels of engagement to exist between "high" and "low engagement" communities. Based on a preliminary analytical framework, I briefly describe below two excerpts of text transcript that illustrate two (of three) engagement dimensions (i.e., the "dialogic and functional" and "structural characteristic"). The first excerpt illustrates substantive "dialogic CMC engagement," a second presents "univocal information exchange." Consider the following cases where the first excerpt elicited four subsequent responses, but the second elicits none at all.

"Dialogic and Functional" Dimension

The following is an illustration of a "dialogic CMC engagement":

> While I absolutely agree that the teaching of five-paragraph essays and other formulas leads to wretched writing and a minimal understanding of organization as only filling in the blanks, I also agree that most students need some scaffolding to understand organization. I would,

however, argue that that scaffolding must be more varied than it may have been in many classrooms, including the ones in which I learned and some of the ones in which I taught!

Integrated or interanimated utterances are coded at three levels, namely lexical, phrasal, and clausal. Consider, for example, "I absolutely agree *that* [italics added]" and "I also agree *that*" are integrated utterances at the clausal level, and the use of "organization" and "five-paragraph essays" at the lexical and phrasal levels, suggestive of Nystrand's uptake.

Moreover, the first utterance above uses the word "agree," in "I absolutely *agree*" and "I also *agree,*" indicating the functional use of another's utterances for specific communicative purposes (i.e., as agreement, with a view to provoking comparison). It also demonstrates the author's awareness concerning the contributors' appropriation of the speech of others as their "thinking device[s]." Secondly, the use of the word, "argue" as in "I would, however, *argue*" clearly demonstrates purposeful use of another's thread utterances as "thinking device[s]" for generating new meaning.

In contrast, consider a typical example of a "univocal information exchange":

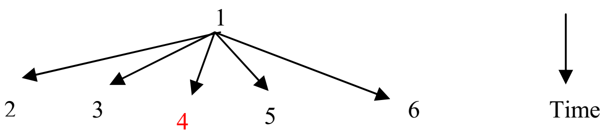
I have a book called Activities for Fast Finishers (Scholastic). It comes in Math, Language Arts and Vocabulary. I got it at Barnes and Noble. The one I have is for grades 4-8… not sure if it would work for your grade level, but you might be able to adapt some of the activities.

In response to a question, the utterances above are characterized by relatively straightforward and factual transmission-like exchanges based on personal experience. Although consideration may have been given to the thread inquirer's status in making the proposal, the respondent makes no reference to the thread's previous utterances nor does s/he use any text for creating new meaning. Such discourse is typically less engaging, more univocal and monologic.

"Structural Characteristic" Dimension

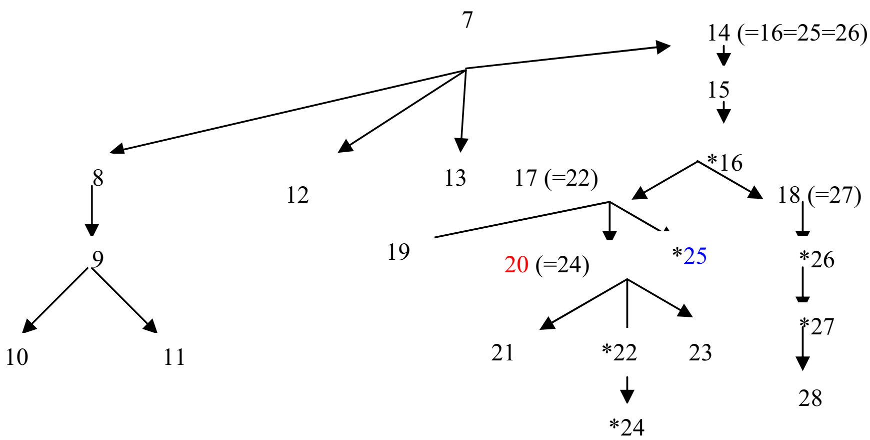
Drawing on the social theories of Schegloff (1999) and Fahy et al. (2001), a "structural characteristic" dimension is operationalized using three engagement indicators (two of which will be briefly illustrated below).

What follows is an overall thread development of a "univocal information exchange."



This figure illustrates linear thread development with only two topic levels, and no development of repeated turns. Each number represents the chronological order of writing authors through time. Engagement increases as reflected by a progression of new arrow nodes (noticeably absent in this example) revealing the quantity, rather than any great depth, of communication. The second excerpt lies in #4.

The next figure shows a representation of "dialogic CMC engagement."



Note. "*" and "=" refer to repeated authors/turns.

In contrast to the first figure, this one reveals a more complex, multilayered participation pattern, with eight topic levels, and the development of repeated turns. The flow is relatively non-linear, evolving with greater bidirectional and dynamic discourse. The first excerpt lies in #20.

RESULTS AND CONCLUDING REMARKS

The empirical findings of the study to date affirm the rationale for my taxonomy of e-communities (i.e., co-constructing “high engagement” versus informational “low engagement” e-communities) on the basis of "CMC engagement." Higher level mastery of dialogic texts as “thinking device[s],” thus markedly contrast with the relatively less engaging discourse of "univocal information exchange." The former category characterizes interaction among sustainable groups.

Three dimensions have been identified for characterizing CMC engagement (“dialogicality and functionality,” “exploration,” and “structural characteristic”), each in turn possessing further identifiable engagement. Furthermore, CMC engagement as expressed between experienced and new teachers is noticeably different. Experienced teachers show greater mastery of “thinking devices[s]” and integrated voices in their speech. In contrast, novice teachers more often appropriate the speech of others, without addressing the reported voice.

This study also provides evidence for the emergence of collective e-communities in supporting new teachers. Conventional boundaries of communities thus needs be reframed as larger dynamic e-communities, comprising synergies of multiple e-communities (e.g., Snyder & Acker-Hocevar, 2003) when engaging in “inquiry as stance” (Cochran-Smith, 2003, p. 7). The findings further challenge, and point to the need to reconsider notions of experts and teaching expertise (e.g., Lieberman & Miller, 2001; cf. Lave & Wenger, 1991), e-learning contexts, and the meaning of putatively objective ontology expressed in critical ethnography (Carspecken, 1996).

This new knowledge of CMC engagement within the e-communities of learners has the following important educational outcomes: (1) a new method for identifying practical ways for e-teacher-educators to optimize their e-learning environment, and their respective roles for leadership and research in education; (2) new policy implications for the impact of e-communities and individual member relations to their pedagogical knowledge and beliefs; (3) accommodation of the differential learning needs of experienced and novice teachers; (4) promotion of empirical explorations of e-research contexts, e-researcher roles, and assessment awareness; and (5) consideration for updating professional development software and training.

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Preserving Authenticity in CoLs and CoPs: Proposing an Agenda for CSCL

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Abstract. This paper reviews the issues of authenticity in learning and educational technologies. Instead of undermining the authenticity of schools or communities of learners (CoLs), we acknowledge schools as having equally legitimate authenticities compared with communities of practice (CoPs). Founded on such an argument, we propose the role of scaffolding learners from CoLs and CoPs. A critical review of approaches to authenticity forms a major part of this paper, and a recommendation of a framework to scaffold learners from CoLs to CoPs with augmentation supports is recommended. We argue that such a process leads to innovation. We recommend an agenda for the field of CSCL to consider.

Keywords: Authenticity, Communities of Learners, Communities of Practice, Scaffolding, Augmentation

COMPUTER-SUPPORTED COLLABORATIVE LEARNING

Computer supported collaborative learning (CSCL) has grown out of an integration of computer supported collaborative work (Ellis, Gibbs, & Rein, 1991) and collaborative learning. CSCL focuses on the *learning* dimensions of what is being communicated and the purpose is to scaffold or support students in learning together effectively. Theories undergirding CSCL include distributed cognition (Hutchins, 1991), Knowledge building (Scardamalia & Bereiter, 1992), Vygotsky's social-cultural theories of the mind (Vygotsky, 1982), cognitive flexibility (Spiro & Jehng, 1991), and other social constructivist forms of learning. CSCL aims at providing both an authentic environment and multiple perspectives that can tie in students' prior knowledge, holding to the underlying assumption that individuals are active agents that they are purposefully seeking and constructing knowledge within a meaningful context. One of the central aims of CSCL is to make learning authentic. In this paper, we argue for the authenticity of both schools and professional practices. We propose an agenda for CSCL to consider how CSCL technologies can bridge between communities through the concept of augmentation supports.

AUTHENTICITY

Authenticity can be observed when students construct meanings and use disciplinary-oriented inquiry processes in their learning (Edelson, 1996). Authenticity from this perspective approximates what the real world is engaged in, that is, the real world of scientists and other kinds of practitioners. Educators have, by and large, deduced from this that learning contexts should be context-rich just as in real world settings (Greeno et al, 1998). Although this is a pedagogically sound end, researchers have been confused with the issue of authenticity being unique in different contexts. We are not denying that perhaps it is into the CoP context that ultimately students would be developed, but this does not give us licence to reject school or CoL authenticity. We argue for the existence of many types of context-community authenticities – CoL-based (school- or university-based community of learners) authenticity and CoP-based authenticity. CoLs are commonly referred to as preparatory communities set up in schools to foster active participation and responsibility for learning goals. By CoPs we mean the actual and 'lived' communities in which practitioners such as scientists engage in their work on issues that have practical implications for society. We contend that these two different types of authenticity serve varying complementary functions and that they are both authentic in their own right.

Constructivist Learning Environments in educational technology (for example, Jonassen 2000, Berman, & Macpherson, 1999) are, in essence, environments where attempts are made to simulate real world scenarios and practices. These environments are also known as practice fields (Senge, 1994). Jonassen (2000) has proposed a framework of 'Constructivist Learning Environments' (CLEs) using communities of practices as activity contexts. A problem is commonly related to situations within real communities of practice (CoPs). The problem can be represented in the form of a story or simulation with the aim that it should be as interesting and appealing to the learners as possible. Jonassen argues for a problem where the learners can affect the problem situation thus enabling it to be more intrinsically motivating. Such a problem would have a context that depicts the social-cultural and organizational context surrounding the problem. A description of the actors, beliefs, goals, organization climate, historical and cultural constrains implicit in the context are described. In the same way, CLEs are simulations because they attempt to transfer problems and processes from CoPs to the classroom. One major problem with any of the above simulation approaches is that a simulation approach is fundamentally a *simulation*, and is therefore not intended to be the same as the actual real world. However, Petraglia (1998) has pointed out that these *a priori* designs – that is, simulation approaches – of constructivist learning environments (CLEs) have missed the in-situ epistemological underpinning of situated cognition (Brown, Collins, & Duguid, 1989). He argues that educational technologists have been preauthenticating learning materials and environments to correspond to the real world rather than fostering learners to interact with it. In essence, only the cognitive dimensions of CoPs are possibly modeled or 'mirrored' into CoL contexts. Recognizing the epistemological significance of Petraglia's work, researchers (for example, Barab, Squire, & Dueber, 2000) have tried to argue for a *participation* approach – that is, instead of bringing the real world into classrooms (that is, simulation approaches), students are brought to the real communities of practices (CoPs) to be enculturated in their learning processes with the central participants of that community (Lave & Wenger, 1991). Thus, from this radical perspective, 'simulating' authentic learning experiences other than through enculturation in the actual full and situated context is an oxymoron with regards to situated cognition.

From a different perspective of practice fields and participation approaches which assume the stability and authenticity of CoPs, relativist approaches address the issue of authenticity from the theoretical groundings of situated cognition. Situated cognition emphasizes the *in-situ* occurrence of meanings in authenticity. In other words, in-situ approaches do not focus on CoLs or CoPs per se, but rather on the processes occurring within the respective communities. Authenticity, in this sense, is judged by the nature of interactions rather than on the 'real-ness' of reality as from CoPs. In-situ approaches spring from situations where two or more parties, for example, learners and practitioners are engaged in mutual co-construction of meanings and understandings. Authenticity therefore emerges from the in-situ processes between parties such as practitioners and learners. The in-situ approaches emphasize that knowing and context are irreducible and co-constituted, and thus learning is conceived of as fundamentally constitutive of the contextual particularities in which it is nested (Davis, Sumara, & Kieren, 1996). Their concern is not with how the cognising agent comes to know the world, but with how learner-and-learned, knower-and-known, self-and-other, personal-and-social, experienced-and-narrated co-emerge, co-evolve, and are co-implicated (Bakhtin, 1981; Davis, Sumara, & Kieren, 1996; Heidegger, 1962; Merleau-Ponty, 1962; Vygotsky, 1978). Both learners and practitioners are seen as *part* of the context (e.g., CoLs) rather than *in* a context. Concomitantly, Merleau-Ponty (1962) has studied patterns of interacting, describing the relationships among persons engaged in conversation as a coupling. This concept has more recently been described by biologists as structural coupling (Maturana and Varela, 1987), co-emergence (Davis & Sumara, 1997), or mutual specification (Varela, Thompson, & Rosch, 1991). Knowledge-in-action (the situated, relativist view) is contrasted to knowledge-as-objects (the dualistic, objectivist view). One example is when K-12 school leaders (as learners) come to the University and co-engage with professors (in the University as a CoP). Much of what emerges in the interactions is a synergy of practical experiences of school leaders (from schools) and the wealth of educational and theoretical knowledge from University professors (as CoP practitioners). Both kinds of knowledge co-determine each other and can result in manifold directions. University professors bring constructivist epistemologies while school leaders are experienced with the possibilities of implementation in practice. In this case, in-situ interactions of meanings occur because University professors recognize their limitations in terms of understanding actual school practices, while these school leaders lack newer theoretical understandings and perspectives. In our discussions above, we have tried to highlight that the in-situ approach, as in co-interactions, occurs in both CoPs and CoLs. In this sense, the relativist-process orientation fits into the authenticity of both CoLs and CoPs. Since both CoLs and CoPs are "equally" authentic, they should exist and not be compared with each other with respect to authenticity. Instead, our proposition is in considering how we can scaffold learners across communities – from CoLs to CoPs.

SCAFFOLDING ALONG THE CONTINUUM OF COLS AND COPS

By adopting Lave and Wenger's (1991) model of legitimate peripheral participation, which is a model grounded on scaffolding and enculturation, we recognize that the above three models can be seen as a CoP learning continuum. With effective scaffolding, we envisage the learner treading from simulation to in-situ interactions. We argue for the need to advance learners through the continuum by appropriating augmented supports through the learning process, yet preserving the construct of authenticity. The concept of scaffolding facilitates the learner within the context of a community moving from legitimate peripheral participation (simulation) to central participation (in-situ) (Lave & Wenger, 1991). In the same vein, as the learner moves along this continuum, the community – which is composed of the learners – similarly evolves along this continuum (Figure 1). The learner has the possibility of progressing from being a novice to finally become an active contributor. These categorizations will be elaborated in the later sections.

An example of a learner being scaffolded along such a continuum could be seen from the perspective of a doctor whose training begins at the University where he or she works with non-life practice fields. On the later years of training, the trainee-doctor begins to contribute alongside qualified doctors in hospital wards, probably engaged in participation with doctor-practitioners in daily activities. Subsequently, after graduation, the full-fledged doctor is now ready for *in-situ* interactions with other doctors as they engage in their own medical cases and research into the frontiers of medical sciences. Other examples could include pilots under training in flight-simulators, pilots subsequently as observer-participants in cockpits, and finally as co-pilots in actual flights. In a similar sense, *scaffolding* is a systemic approach to supporting the learner (Jonassen, 1999), focusing on the task, the environment, the learner, and other instructional persons such as tutors, teachers, etc. That is, scaffolding provides structures and frameworks to support the learning process and students' performances beyond what is currently possible (Griffin & Cole, 1984).

Legitimate peripheral participation   Central Participation

Learner is a   novice   observer   participant   active contributor

Practice Fields ⟶ Participation ⟶ In-situ emergence of meanings

Figure 1: The scaffolding continuum

A scaffold adapted to the level of the learner ensures success at a task difficult for the learner to do on his or her own. Scaffolding envisages a learning structure and framework for a learner to gradually move along a continuum. Scaffolding usually involves the notion of gradual fading and removal of supports. Tools or resources are initially needed and may gradually be internalized as learners progress in the learning continuum. Again, one needs to differentiate between the supports afforded by scaffolding and those that are used to augment the learner's capabilities. Once the learner is fully immersed in the professional culture of the community, these tools resources can be gradually removed. In retrospect, the design of simulation-oriented learning environments is complementary to real communities and not a replacement for them. Obviously, the real context (non-simulation) with its embedded nuisances would probably be the best. However, we recognize that it is not always feasible to have full participation with communities of practice from the initial stages of the learning process – it defies the peripheral to central participation concepts of learning within communities (Lave & Wenger, 1991).

An example of a learning environment which can scaffold between CoLs and CoPs is *ChemSense*. *ChemSense* can be seen as a tool bridging learners from CoL to CoP. Kozma's (2003) *ChemSense* allows learners to see chemistry concepts, such as chemical bonds, in multiple representations because the research findings showed that expert chemists are able to see chemistry meanings in multiple representations. On the other hand, novices or students are constrained in their ability to visualize and are generally not able to recognize chemical meanings in multiple forms, for example, between bond-structures and actual laboratory chemical experimentations. The background of to such an environment is the recognition that students think "chemistry" rather differently from "experts" or practicing chemists. In other words, the way students learn chemistry in schools or CoLs differs from the way chemists "see" meanings in CoPs. Hence, ChemSense, although not intended to be a bridging CoL-CoP tool can serve this function. *ChemSense* would augment the novices thinking by displaying alternative representations to novices – chemical equations, real-time graphs representing phenomena, molecular animations, and videos of lab-based experiments (Kozma, 2003). If *ChemSense* is also used in real CoPs where chemists can benefit from, the bridge between CoLs and CoPs is augmented. In this sense, *ChemSense* can be used as an augmenting support that helps to facilitate interactions across both communities. In other words, *ChemSense* can be used in both CoLs and CoPs and as a mediator between both communities. Basically an augmentation support mediates the interactions between two or more communities. At this stage, we want to conceptualize on the concept of augmentation supports. To our minds, augmentation supports, unlike scaffolds, do not fade away as students are scaffolded from CoLs to CoPs. ChemSense for example, can be appropriated by both CoLs and CoPs – used by both students and experts. We hypothesize at this stage that there can be environments which span both CoLs and CoPs and these environments should be intentionally designed as augmentation supports. In other to preserve the authenticity of both CoLs and CoPs, we recommend that the field of CSCL consider how augmentation supports can be an integral part of its agenda.

SETTING AN AGENDA FOR CSCL – AUGMENTATION SUPPORTS

The work of bridging between communities can be a fruitful agenda for CSCL. We propose that CSCL consider the work of supports which *do not fade away*. Augmentation is contrasted with scaffolding. Scaffolding is depicted by a process where supports are provided to the learner to achieve a certain goal without which the individual would not be able to attain to. These supports generally fade away after the learner appropriates the skills and knowledge required. The learner grows out of dependency on these supports. We conjecture in this paper that there are supports which do not necessarily fade away in the learning process, which we term as augmentation supports. We propose educational technologies and learning environments where supports are "superimposed" onto the learning experiences. For example, the learner is engaged in the real authentic problem case with supporting tools and resources. We see a potential in using simulations (including VR oriented cognitive tools and information resources) to assist the less experienced to effectively engage themselves in the community. Such augmentation supports 'assist' rather than 'instruct'. *Instead of fading away, augmentation supports go with the learner as he or she transits from one form of community, for example home or school, to another form such as communities of practice (CoP). We make the assumption that learning is progressive when learners progress from schools to CoP-forms of understanding.*

Augmentation can be in the form of tools, artifacts, and even "persons". Augmented tools are basically instruments and models which are used by practitioners in communities of practice (CoPs), for example, the microscope, the various measuring devices, etc. Other kinds of augmented tools include specific instruments for domain related activities such as devices which compute data for certain forms of activity. Augmentation tools can also be in the form of supporting personalized knowledge representations in the context of social spaces in online collaboration -- personalized representations can be superimposed/augmented onto social and collective representations. Augmented artifacts are cases, living stories, accounts, and ideas which literally occurred in real CoPs which can be used in schools as illustrations and resources where students can refer to as examples in their pursuit for understanding. Current knowledge management literature strongly promote the use of real case testimonies and stories as situated examples for learning. Learners need access to relevant cases or stories pertinent to them as they engage in context-dependent situations. Researchers and designers believe that instructional materials supporting ill-structured problem-solving skills should incorporate cases that represent (as close as possible) real-world cases and problems in that particular domain (Jonassen, 1999). The use of stories or cases in problem-solving education increases problem-solving skills, helps address misconceptions, and contributes to the changing of attitudes. Augmented persons are practitioners who can go into schools and communicate with students. These augmented persons act as consultants and experts, mentoring the learners by modeling expert-thinking and behaviors. These augmented persons also help to bridge the gap between schools and CoPs as the learners move into the context of practices and real work communities. The augmented persons do not fade away and continue to be a strong influence to the learners from schools to CoPs.

To summarize, augmented tools are cognitive and physical instruments which learners *work or think with* in relation to their authentic learning experiences; augmented artifacts are materials – both conceptual and physical – which learners *work and think upon* as exemplars; whereas augmented persons are facilitators and experts which learners *work and think alongside.*

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V-Share - Video-Based Analysis and Reflection of Teaching Experiences in (Virtual) Groups

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Abstract. Successful teacher education links methodological theory and teaching practice. Research further indicates that student teachers' development of pedagogical content knowledge can be fostered if they are supported in reflecting on teaching experiences individually and cooperatively. Time and place independent pre- and in-service teacher training is gaining importance. Due to long distances between individual student teachers and the limited amount of time for reflection during face-to-face sessions, analysis and reflection processes cannot be realized in blended learning arrangements with the same means available in traditional face-to-face teacher education. The project "v-share" therefore develops the methodological concept and technical support for video-based analysis and reflection on teaching experiences in (virtual) groups. The internet-based tool allows student teachers in blended learning arrangements to share videos of their own and their fellow student teachers' teaching lessons and to select sequences for joint online analysis, annotation and reflection.

Keywords: video-analysis and -annotation, teacher training, blended learning, reflective teaching

INTRODUCTION

Reflection on practice is of importance because it enables practitioners to assess, understand and learn through their experiences. A positive active process of reflection that reviews, analyses and evaluates experiences draws on theoretical concepts and previous learning and so provides an action plan for future experiences (Kemmis, 1985). Instructional measures that foster student teachers' reflection skills and develop attitudes which are considered necessary for reflection effectively seem to be, among others: teaching student teachers self-regulatory strategies such as planning, self-controlling and self-assessing activities, as well as allowing them to share their experiences and to articulate their reflective thinking processes with lecturers and fellow student teachers (Dewey, 1938/1986; Schön, 1987). Additionally, the lecturer's role is essential in focusing student teachers' reflection processes on teaching situations and reflection processes which may pass by without the participants' awareness (Hovelynck, 2000). Furthermore, several learning-to-teach studies indicate that student teachers who are required to structure and verbalize the pedagogical content knowledge underlying their teaching succeed in distancing themselves from their actions and are thereby able to reflect on them. The development of this capacity of reflection-on-action (Schön, 1987) seems to be enhanced by having student teachers carry out classroom research projects.

Time and place independent pre- and in-service teacher training is gaining importance. According to the concepts of experiential and inquiry-based learning, the planning and carrying out of lessons and the inquiry-based reflection on teaching experiences should be important learning activities of blended learning teacher training courses, too. Due to long distances between individual student teachers and the limited amount of time for reflection during face-to-face sessions, analysis and reflection processes cannot be realized in blended learning arrangements with the means available in traditional face-to-face teacher education. What lacks most of all is the possibility to reflect cooperatively on shared teaching experiences by engaging in a focused inquiry dialogue with lecturers and peers.

The research project v-share is developing the methodological concept and the technical support for video-based analysis and reflection on teaching experiences in (virtual) groups. The underlying assumption is that the purposeful observation and the guided sharing of analyses and reflections on video-recorded lessons foster student teachers' capacity for reflection-on-action and – in turn – improve teaching abilities.

In the first part of this paper we describe the pedagogical design of v-share considering the three main aspects of the research project: using video, collaborative learning and moderation. In the second part follows an outline of how v-share is used at the University of Education in Freiburg. Thereafter the technical realization of v-share is described. Finally the use of v-share as a research tool is put forward.

PEDAGOGICAL DESIGN

Using video

In the research project v-share, video-recorded lessons are used for analysis, annotation and reflection on teaching practices. In comparison with traditional teacher training methods which make use of direct observations followed by face-to-face discussions, video analysis has its own challenges. Unless a 360-degree video camera is available (cf. Roschelle, Pea & Trigg, 1990), video cameras can only capture a limited region of the whole classroom. Therefore, events taking place outside this region cannot be observed during the video analysis. This clipping can be minimized, however, by instructing the video grapher by means of a lesson plan that describes the different parts of the lesson and the main actors. Furthermore, the knowledge of being filmed can affect the behavior of pupils, teachers and student teachers (cf. Hiebert et al., 2003).

Although it is very difficult to detect all important classroom events and interactions in real time, the analysis of video-recorded lessons has several significant advantages in comparison with direct observation. For instance, without video lecturers and student teachers have to rely exclusively on written notes and their memories. Furthermore, video offers the possibility to view a lesson several times and to focus each time on different aspects of a lesson. This allows observers to adopt multiple perspectives on a lesson (Van Es & Sherin, 2002). Video-recorded lessons also make it possible for people to participate in the analysis and discussion who were not able to participate in the lesson itself. According to Clark's (1996) theory on achieving common ground in communication, video-recorded lessons may also serve as a shared external reference point for discussion. Instead of verbally circumscribing the part of a lesson student teachers like to refer to, they can easily refer to it by showing the corresponding video sequence.

Collaboration

In the project v-share, the analysis, annotation and reflection on video-recorded lessons take place in small groups. Collaborative analysis of teaching practices results in different perspectives on one and the same lesson. According to the socio-constructivist theory of learning (e.g., Doise & Mugny, 1984) student teachers learn from different perspectives when they identify and resolve them, present alternative views as well as provide and ask for explanations. Furthermore, the theory of cognitive dissonance (Festinger, 1957) states that the existence of different interpretations among the members of a group induces cognitive dissonance in the individuals. This encourages the individual student teachers to reduce dissonance by communicating with their peers and by revising his/her point of view. Research of Stevens (1997) using the video-analysis-tool "Video Traces" supports this theoretical background and underlines the importance of collaborative use of video.

In contrast to traditional teacher training seminars, the analysis, annotation and reflection on teaching practices take place by making use of a web-based bulletin board. While in synchronous face-to-face settings only one student teacher can contribute to an analysis at a time, a bulletin board allows for asynchronous communication as well as for several contributions to an analysis at a time. This might be of special importance during phases in which ideas need to be generated and collected and cognitive blocking of contributions due to waiting times are to be avoided (e.g., Diehl & Stroebe, 1991). In addition, Quinn et al. (1983) observed that contributions to asynchronous discussions are more detailed and elaborate than contributions to synchronous discussions due to the lower frequency of turn taking. Features such as the written elaboration of contributions, the reversibility of contributions and the lack of time pressure during the formulation of contributions should further increase the quality of contributions (cf. Clark & Brennan, 1991). Furthermore, cognitive resources bound to paraverbal and nonverbal behavior in face-to-face communication is freed and can be allocated to writing contributions in computer-mediated communication (cf. Matheson & Zanna, 1988).

Moderation

As described above, computer-mediated communication has several advantages compared to face-to-face communication but also poses specific difficulties. The missing synchronicity in computer-mediated communication can easily lead to a mixture of contributions, replies to contributions and the creation of new threads and thus produce a complex discussion structure that makes it difficult for the student teachers to construct a coherent view of the discussion and to reach shared understanding (e.g., Levin et al., 1990). Therefore, within the v-share project the lecturer assumes the role of a moderator. She or he assigns tasks to certain student teachers, encourages student teachers to resolve and to integrate different perspectives, raises stimulating questions when the discussion makes no further progress and provides summaries in order to foster coherence building, for example.

USING V-SHARE FOR ANALYSIS AND REFLECTION

Since the summer term 2004 v-share is being used in teacher training seminars at the University of Education, Freiburg. The seminar's methodological concept is based on the principles that favor the development of student teachers' reflection competence, as described above. During the seminar, various teaching methods are discussed while taking student teachers' learning biographies into account. Student teachers devise criteria for specific teaching methods such as the sequence of teaching activities and the role of the teacher as well as the role of the learners. Based on the above-mentioned criteria student teachers develop lesson plans. They individually select a reflection focus for their lesson, which might derive from teaching theory, methodological or personal matters. Building on this, the lecturer and the student teachers jointly develop observation sheets, which help to focus the observation of the lesson in the classroom as well as the analysis of the video-recorded lesson on the student teacher's point of interest. The student teachers teach lessons individually or in pairs. Specific parts of the lesson are recorded by means of a digital camera and are archived in a discussion board. Following the principle of ownership this is done by the student teacher who taught the lesson in question. The selection is based on the observation sheet that the student teachers developed in a further step and on personal relevance of specific scenes for the student teacher. The participants are aided by a tutor who is an expert in using video-cutting software and has the ability to encode video for internet-streaming. The different video sequences are time-stamped in the video frame to make clear when a scene took place in the lesson. On the basis of theory-based feedback, first the student teacher, then his/her fellow student teachers comment on selected video sequences. Before the student teachers have to comment on the video sequences for a second time, the lecturer focuses the reflection process on points of relevance. The reflective process concludes with a synopsis written by the student teacher who taught the lesson in question.

All steps just described are supported by the internet-based v-share workspace that is used by the student teachers throughout the term. At the beginning of the seminar all student teachers register at the v-share workspace by entering their personal data (e.g. name, email-address, photo). Using name and password the student teachers are then able to access the workspace. All content created by the student teachers is now personalized with the data they entered in the registration process, which increases the degree of environmental and personal presence (Sadovski & Stanny, 2002). The student teachers use v-share to publish the documents they are writing throughout the seminar. This includes the writings on their learning biographies, their summaries of theoretical articles, the observation sheets and the lesson plans they develop and last but not least the synopses they write. v-share supports the self-creation of documents in the workspace as well as the uploading of existing documents as attachments. The self-creation is aided by a rich text editor which enables the student teachers to use different fonts, colors, listings, etc. The published content can also be re-edited by the author ex post which increases reversibility.

Analyzing and commenting on the recorded video-sequences are supported by a combination of a video-player and the bulletin board. The video-player on the left hand side (see Figure 1) allows the student teachers to play back the video-sequences and to select sub-sequences by choosing in- and outpoints. This enables the student teachers to specify parts of the lesson which they would like to comment on and link this comment to a video-sequence. After submission, the comment is shown on the right hand side of the page (see Figure 1). Every comment includes a button to show the corresponding video-sequence in the video-player which enables the student teachers to refer back to the situation in the corresponding lesson. Furthermore, student teachers can reply to each other's comments and quote comments of their fellow student teachers.

Figure 1: The v-share workspace (www.v-share.de).

All entries are organized in a treediagram with comments as roots and replies as branches of the trees. The board offers the possibility of expanding certain trees of interest and collapsing all other trees. Every message shows the author's name and photo in order to personalize the comment at first sight. Video and bulletin board can be synchronized: In synchronization-mode the comments that belong to a video-subsequence are highlighted automatically while playing the video. This aids participants of the seminar who want to gain a first overview of the comments their fellow student teachers have already written. Furthermore, not only can the comments be linked to the video-sequences but also parts of the synopsis that the student teachers write as a conclusion of the reflection processes. This makes it easy for fellow student teachers to refer back to parts of the lesson which the student teacher who taught the lesson mentioned in his/her synopsis. Finally, the integration of teaching theory, lesson planning, video-linked comments and synopsis in one integrated workspace enables "third-party-students" to "replay" the process.

A main goal in future developments of v-share will be the realization of easy-to-use functionalities to link all content elements available. For instance, statements in comments could be verified by linking them to sentences in a theory article or the synopsis may be linked to comments written by fellow student teachers. This should encourage the student teachers to verify their propositions and reduce effects described in the messaging threshold approach (Reid et al., 1996).

TECHNICAL REALIZATION

v-share is integrated as a self-programmed extension in the open source application framework Typo3 (see www.typo3.org). Typo3 allows the creation of complex websites based on HTML-Templates. The pages can then be filled with different content elements such as texts and pictures without the need for HTML or other programming skills. Typo3 is based on the open source database MySQL and the popular scripting language PHP which simplifies the development of the v-share workspace. The Typo3 framework provides a pre-built administration environment (the backend) for content creation and distribution. Like any other content element that is provided by Typo3, the v-share bulletin board can be included on any page. Installation and configuration of the v-share extension is completely handled by the backend which makes it easy for lecturers to use a v-share workspace. By default, Typo3 already supports user and group authorization and authentication methods which can easily be used in self-programmed extensions like the v-share workspace. Creation of groups and mapping of users to groups can be done in the backend, too. There is a wide range of already developed extensions that can be seamlessly integrated in any Typo3-based web page available for use in the v-share workspace, such as tools for synchronous and asynchronous communication or for workspace awareness, for example.

The heart of the v-share workspace is the video-bulletin-board combination. It makes use of different web-technologies: JavaScript reads out the actual time stamp of the video-playhead when the user selects the in- and outpoint of the sequence he/she wants to comment on. When submitting the comment, the subject, the text, the attached files, user information and the corresponding in- and outpoint are passed to the MySQL database using PHP as a scripting language. This data is retrieved from the database when displaying the bulletin board.

The configuration possibilities include selection of the video-file that is used in the board, specification of user-groups with the rights to write, declaration of the moderator of the board who can edit, move and delete any post and the possibility to allow for replies. For instance, the lesson plan also relies on the v-share board file-upload functionality without inheriting the reply-function. For research purposes, the use of video is adjustable, so the board can be used with or without video.

The recorded video-sequences are coded in the RealPlayer-format for delivery over the web. Real is one of the most popular media codes and players are freely available for all major operating systems. The surestream technology provided by Real allows the delivery of videos that suit the bandwidth of the user. When detecting a high-bandwidth connection like DSL or direct connection in universities the server automatically delivers high-quality video while concurrently giving the student teachers the chance to show low-quality video over their low-bandwidth modem or ISDN connection at home. To distribute surestream-videos, the Helix DNA server is mandatory. It is available under open source license. RealPlayer also supports the Synchronized Multimedia Integration Language (SMIL). SMIL offers possibilities to combine audio, video, text and graphics in real time and to control dynamic web pages. In the current version of the v-share workspace SMIL is used for highlighting corresponding comments while playing the video in synchronization-mode. In future releases, SMIL might be used to show a combination of video and corresponding comments in one integrated view.

V-SHARE AS A TOOL FOR EMPIRICAL RESEARCH

Making use of v-share as a research tool, we are currently following three lines of research. In the first line of research, we analytically develop and empirically test criteria which allow us to describe and assess student teachers' reflections on teaching experiences. On the one hand, these criteria indicate how well the student teachers observe their own behavior and the pupils' reactions and how well they succeed in integrating theoretical, personal and contextual perspectives. On the other hand they illuminate to which extent the conclusions drawn by the student teachers are related to their reflection process.

On the basis of the developed criteria, in the second line of research we empirically compare different arrangements of using v-share. As a first step, we are currently running a three-term long field study (summer term 2004, winter term 2004/2005, and summer term 2005) at the University of Education, Freiburg. In this field study, v-share is employed in university courses on developing teaching practices. The three main goals of the field study are (1) to gather experience with v-share in everyday teaching, (2) based on the lecturers' as well as the student teachers' experiences, to adjust v-share's design and (3) to enable the development and testing of the criteria mentioned above. In a second step, more controlled quasi-experimental studies will be conducted in order to empirically test various assumptions underlying the design and use of v-share. For example, it will be tested whether videos taken during teaching practices support student teachers' reflection and communication processes to the assumed degree. Furthermore, as is well-known from research on computer-supported collaborative learning, if computer-mediated reflection and communication is to be successful, it needs various forms of support (e.g., Hron, Hesse, Cress, & Giovis, 2000). This is especially true if the lecturers as well as the student teachers are not used to collaborating in a distributed setting. As v-share has been designed in such a way that it allows for the structuring of collaboration in different ways, it will be utilized to empirically compare the effects of different collaboration structures on the reflection and communication processes.

In the third line of research, v-share will not only be used to support reflections on teaching practices made within a small group of student teachers. Rather, v-share will be extended with a database accessible through the internet that consists of a library of – selected and rather short – teaching episodes classified according to specific pedagogical criteria (cf. Derry, Seymour, Lee & Siegel, in press). With respect to such a database, v-share serves two different purposes. Firstly, it provides a tool for demonstrating and collaboratively discussing teaching episodes in courses and seminars on teacher training. Secondly, by importing videos of teaching experiences taken during new teaching practices into v-share, pedagogically interesting video sequences might be suggested for closer review and – if approved – be classified and entered into the database.

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CSCL - The Next Ten Years – A View from Europe

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Abstract. This paper reviews some foundational issues that affect the progress of CSCL. In particular we examine the terms technology, affordance and infrastructure and propose a relational approach to their use in CSCL. Following a consideration of networks, space and trust we propose an indirect approach to design in CSCL. The paper is based on the outcomes of two European networks, E-QUEL a network on e-quality in e-learning and Kaleidoscope, a European Union Framework 6 Network of Excellence and the 'Conditions of productive learning in networked learning environments' project in particular. This paper does not aim to be comprehensive or summative rather it provides a view of current issues and perspectives from a European point of view.

Keywords: CSCL, networked learning, ethics , affordance, design.

INTRODUCTION

Computer Supported Collaborative Learning is an emerging field of research and interest still struggling within itself and arguing over its very name (Koschmann, 1996, 2001,Strijbos, Kirschner and Martens 2004). However, seen from a sociology of knowledge perspective CSCL is a scientific field and a scientific community with conferences, journals and educational programs. Due to the very nature of the object of research: Computer Supported Collaborative Learning, it's an interdisciplinary field drawing on various disciplines such as learning, anthropology, psychology, communication, sociology, cognitive science, media and informatics.

We argue that despite the variations in topic and method what knits the field together and what makes it special is the *integration* of the four key concepts: computer, supported, collaborative, and learning. However, in some of the recent work reflecting on CSCL there is a questioning of the necessity for integrating technology into CSCL:

> "CSCL research has the advantage of studying learning in settings in which learning is observably and accountably embedded in collaborative activity. Our concern, therefore, is with the unfolding process of meaning-making within these settings, not so-called "learning outcomes". It is in this way that CSCL research represents a distinctive paradigm within IT. By this standard, a study that attempted to explicate how learners jointly accomplished some form of new learning would be a case of CSCL research, even if they were working in a setting that did not involve technological augmentation. On the other hand, a study that measured the effects of introducing some sort of CSCL application on learning (defined in traditional ways) would not". (Koschmann 2001 p 19).

Strijbos, Kirschner and Martens (2004 p1, p 246) make a somewhat different point, but they also take a non-technological stance. For these authors the emphasis in CSCL is on learning and the weakness in CSCL is in learning and educational design. Unlike Koschmann we think it is necessary and challenging to keep technology within our focus. Unlike Strijbos et al we see the technological aspect deeply integrated in a socio-cultural theoretical approach to the understanding of collaborative learning. The technology has to be taken seriously because this is precisely what makes this research area special. In our opinion it is where CSCL has something profound to contribute to the field of learning.

Much of the research that has taken place within CSCL has focused on the micro level of collaborative learning, on the collaborative learning in single groups. Supplementing these approaches, we would like to argue for more focus on the meso-level of collaborative learning:

- On how to design for collaborative learning in organisations, school settings, and in networked learning environments
- On what the conditions are for collaborative learning in these settings
- On how the technology and infrastructure affords, and mediates the learning taking place

In this way we would like to throw light on the field of CSCL from the lenses of educational research, human centred informatics and social sciences. In doing so:

> "One needs, first of all, the right vocabulary for thinking about the phenomena that occur on levels of analysis that we are not familiar with discussing. We need appropriate conceptual resources and analytic perspectives. This is what is meant here by a ´theory´" (Stahl, forthcoming p. 5).

In the following, we are not providing a theory, however in line with Stahl, we would like to contribute to the process of establishing a meaningful conceptual framework for the understanding of conditions for productive learning in networked learning environments. To understand the new emerging practices and contribute to the productive development of them, we must develop conceptual tools. This is even more necessary because of the interdisciplinary nature of the field. Integrating concepts from different disciplines involves a cost in terms of the intellectual work necessary to ensure that the historically embedded meaning travels with the concepts, and that the concepts are rethought and integrated in the perspective of the new practices and the insights from neighbouring disciplines. The general theoretical framework adopted in this work can be described as socio-cultural in a broad sense and it draws on the works of Vygotsky (1978), Engestrøm (1987), Lave & Wenger (1991), Wenger (1998), Giddens (1984), Castells (1996/2000), and Dewey (1916). Because these traditions are in some ways contradictory, with regards to epistemology and methodology, there has to be profound work and discussion., both on ways to solve these contradictions and if it's productive to try to solve them.

In the following sections we will be dealing with some of the key theoretical concepts which have emerged from the work in two European projects and networks, E – QUEL, (http://www.equel.net/), and Kaleidoscope, a European Union Network of Excellence (http://www-kaleidoscope.imag.fr). We will focus on two sets of issues: firstly, technology, affordances and infrastructure and secondly on networks, space and ethics. These have emerged in our work as crucial to understanding the conditions for productive learning in networked learning environments.

TECHNOLOGY, AFFORDANCES AND INSTITUTIONS

We argue that the concept of technology and the relation between the design of technology and the use of technology is crucial within the CSCL community. Vygotsky's socio-cultural approach is deeply accepted and even taken for granted in the CSCL community (Vygotsky 1978, Cole 1996, Kaptelinin, Danielsson and Hedestig 2004). Both the material and symbolic properties of tools are seen as having important implications for understanding how internal processes come into existence and operate (Fjuk, and Berge 2004). In order to understand these processes, Fjuk and Berge argue, that analysis and design must consider the individual learner in her/his concrete situation and the mediational means employed. A similar position on the necessity of studying practice is elaborated by Orlikowski (2000). Orlikowski suggests making an analytical distinction between the use of technology, what people actually do with technology, and its artifactual character, the bundle of material and symbolic properties packaged in some socially recognizable form (ibid. p. 408). Through a theoretical and empirical analysis she demonstrates that the same artifact used in different institutional contexts and by different actors, enacts very different actions.

Theoretically, these different processes are explained by Orlikowski using structuration theory (Giddens, 1984), and she makes a distinction between two discrete approaches (op.cit pp. 405):

a) which posits technology as embodying structures (built in by designers during technological development), which are then *appropriated* by users during their use of the technology
b) a practice-oriented understanding where structures are emergent. Structures grow out of recursive interactions between people technologies and social action in which it's not the properties of the technology per se which structure the practice. Rather it is through a recurrent and situated practice over time, a process of *enactment*, that people constitute and reconstitute a structure of technology use. (Orlikowski op. cit. p. 410).

The practice-oriented structurational approach to technology (b) suggests that the technology embodies particular symbolic and material properties, but the technology in itself is not a structure, which determines the use and the users. Rather the opposite, the structure – understood as resources and rules - is instantiated and emerges through the users' responses and enactment in relation to the technological artifact. However we would go on to argue that Orlikowski may present too strong a contrast between the approaches summarized above in a) and b). Seen from the practice of design, technologies do indeed embody features and properties and they also carry meaning having been designed with certain purposes in mind, embedding certain understandings of communication, interaction and collaboration. Furthermore as Stahl (2005, forthcoming) formulates the question, though the designs carry meaning, and the tools have been designed with certain purposes in mind, how the users respond to or enact the technology cannot be predicted and it is in and through practice that the structural features will emerge.

Another way to deal with this question is to examine how we conceptualize technology. In her paper, Orlikowski counter poses technology thought of as:

a) "an identifiable, relatively durable entity, a physically, economically, politically, and socially organized phenomenon in space-time" – technological artifact
b) " a repeatedly experienced, personally ordered and edited version of the technological artifact" – technology in use (op. cit p408)

She makes it clear that this distinction is analytic rather than ontological in character but our work leads us to question the usefulness of this distinction in relation to certain kinds of technology. In particular we wonder whether the Web or Internet can usefully be thought of as technological artifacts. We would support the general position that Orlikowski seeks to maintain but we are concerned that conceptions that apply the metaphor of artifact to large, complex and composite forms such as the Web and Internet are in danger of reifying a deeply reflexive phenomenon. In important ways the Web and Internet do not fully conform to Orlikowski's criteria. Though relatively durable they are constantly in flux, though organized they show an uncommon self-organizational capacity. We suggest that the idea of technology and in particular technological artifact is an area ripe for further CSCL research, especially in relation to large scale and composite technological forms such as the Web and Internet.

Affordance

The concept of affordance has been central to thinking about technology within the CSCL tradition and beyond. It has recently been applied to technology in the sense that:

> "technologies possess different affordances, and these affordances constrain the ways that they can possibly be' written' or' read'." (Hutchby 2001 p447)

Affordance used in this way allows for the possibility of technologies having effects and the idea that particular technologies can constrain users in definite ways. The idea has its origins in the work of Gibson (1977) who was interested in the psychology of perception. Affordances in Gibson's view varied *in relation* to the user but they were not freely variable, the affordances of a rock differed from those of a stream, even though different animals might see the affordances of each differently. The Gibsonain view is strongly relational and differs in significant ways from the later application of the idea of affordance by Norman (1990) and Gaver (1996). These authors have an essentialist and dualist approach in which technologies possess affordances and users perceive them. All three authors have recently been reviewed by Kirschner, Strijbos and Martens (2004) who emphasize the distinction added by Norman between an affordance as a property possessed by an entity and an affordance as it is perceived. Kirschner, Strijbos and Martens (2004) suggest that educational researchers and designers are not dealing with the affordances of technologies themselves; instead they are dealing with the perceptible (Gaver 1996) or the perceived (Norman 1990).

Kirschner, Strijbos and Martens (2004) propose a six-stage model for a design framework based on affordances. This sophisticated and detailed model categorizes affordances as educational, social and technological. They define educational affordances as "those characteristics of an artifact that determine if and how a particular learning behavior could be enacted within a given context." (op.cit p14). Social affordance is defined as "properties of a CSCL environment that act as social-contextual facilitators relevant for the learner's social interaction." (op.cit p15). Technological affordances, after Norman (1990) are "perceived and actual properties of a thing, primarily those fundamental properties that determine how the thing could possibly be used." (op.cit p16). All three definitions rely upon an essential reading of affordance, on the *properties* and *characteristics* of CSCL environments, artifacts and things, even if the affordance relies on being perceived.

The view of affordance that we have begun to consider and would propose to the CSCL community is one that returns to a Gibsonian view and treats affordance as a *relational* property. In this way of thinking about affordances properties exist in relationships between artifacts and active agents, which would include animate actors and following Callon and Latour inanimate actants. This view is non-essentialist, non-dualist and does not rely on a strong notion of perception. Affordances in this view could be discerned in a relationship between different elements in a setting whether or not the potential user of an affordance perceives the affordance.

In educational settings we are likely to be concerned with reflexive social relationships. A relational view of affordance would suggest that we could analytically discern features of the setting apart from the perceptions of particular groups of users. Any actual group of users would have varied understandings and draw out different meanings from the setting but designers can only have direct influence over those abstract elements, that may become affordances in the relationship between the designed setting and the participants. An example of such relational thinking can be found in Kreijens and Kirschner (2004). They point to the affordance of proximity in encouraging face-to-face interaction and they point to the need for teleproximity in computer networks. The affordances of both proximity and teleproximity rely on the relationship between participants rather than being a feature of any particular participant or a feature of the digital or real environment.

Infrastructure and institutions

Implementation of CSCL in higher education is a complex task involving management, administration and ICT support as well as teachers and learners. Research in CSCL recognises that influences on practice arise from an organizational as well as a pedagogical perspective (Collis and Moonen 2001; Dirckinck-Holmfeld and Fibiger 2002). Nyvang and Bygholm (2004) draw on the works of Star and Ruhleder (1996). They suggest that we interpret ICT in use as infrastructures that both shape and are shaped by practice and go on to propose that we understand infrastructure as a relational concept. "*Thus we ask, when – not what – is an infrastructure"* (Star & Ruhleder 1996, p. 113). This understanding of infrastructure has strong resonance with the earlier accounts of technology and affordance and we would suggest that the infrastructure for CSCL is a location in which these general issues find focus for research.

In a recent case study of a Masters level program Jones (2004a) argues that obtaining a single login to enable all students on a distance taught program access to digital resources is a multi-level problem. The required digital resources are enmeshed in a legal framework of ownership concerned with property rights. Access to the materials and resources available for teaching and learning is not a simple matter as some of the materials are ephemeral with links moving or disappearing on a regular basis. Secure resources have to be embedded in an institutional and organizational infrastructure that takes on some of the roles, such as preservation, that libraries have hitherto fulfilled. This institutional support may be external to the university and even the educational sector, as with government, NGO and corporate supplied materials. When resources become organizationally supported they often disappear from the Web's open access behind password protection. The creation of a single log-on authentication for staff and students and a public 'commons' for educational materials is a political, legal and social process well beyond the control of single educational program.

We have argued that technology, affordance and infrastructure are terms that the CSCL community may need to revisit. We have suggested that all three may be better understood using a relational perspective. We have also set out a number of ways in which we think this approach may lead to new research directions. The idea of technology and in particular the idea of technological artifact is an area ripe for further CSCL research as we argue technology and the affordances that may emerge in its use are factors that require investigation at a more macro level than has been usual in CSCL.

CONDITIONS FOR PRODUCTIVE LEARNING

Castells (2000) writes about inclusion/exclusion in networks, and the architecture of relationships between networks, enacted by information technologies, which configure the dominant processes and functions in our societies. Castells describes the network society as one of 'networked individualism' (Castells 2001p129 ff). On the one hand the new economy is organized around global networks of capital, management, and information, whose access to technological know-how is at the roots of productivity and competitiveness. On the other hand he claims that the work process is increasingly individualized:

> "Labour is disaggregated in its performance, and reintegrated in its outcome through a multiplicity of interconnected tasks in different sites, ushering in a new division of labour based on the attributes/capacities of each worker rather than the organization of the task" (ibid. 502).

This general trend raises fundamental questions about the relationship between the networked society and the organization of learning environments within formal education. We believe it is a significant question for CSCL whether the designs of networked learning environments have to reflect the trend towards 'networked individualism' or whether CSCL may serve as a counter practice offering opportunities for developing collaborative dependencies in networked learning environments.

The idea of networked learning has developed some force within European research, expressed in a number of publications and a series of international conferences. One definition of network learning from this tradition is that:

> Networked learning is learning in which information and communication technology (C&IT) is used to promote connections: between one learner and other learners, between learners and tutors; between a learning community and its learning resources (Jones 2004 a p. 1).

The central term in this definition is *connections*. This definition takes a relational stance in which learning takes place in relation to others and also in relation to learning resources. Networked learning differs here from CSCL and Communities of Practice in that it does not privilege relationships such as cooperation and collaboration or the close relations of community. Unlike CSCL and Communities of Practice this definition of networked learning draws particular attention to the place of learning resources and peer learners in relational terms (For further elaboration of this view see Jones 2004, Jones 2004 b and Jones and Esnault 2004).

European research and practice has been heavily influenced by Communities of Practice thinking and other learning environments for professionals have built more explicitly on ideas of communities of practice and the pedagogical principles of collaborative learning. For instance in the form of problem and project based learning, encouraging and expecting students to work together (See for example Dirckinck-Holmfeld, 2002, Fjuk and Dirckinck-Holmfeld, 1997). The concept of communities of practice is most commonly associated with Wenger (1998). For Wenger, networks are not necessarily in opposition to the ideas of communities of practice. Wenger suggests that a network with strong ties resembles a community.

> "Communities of practice could in fact be viewed as nodes of "strong ties" in interpersonal networks" (1998 p. 283)

However, he also stresses the difference in purpose:

> "…but again the emphasis is different. What is of interest for me is not so much the nature of interpersonal relationships through which information flows as the nature of what is shared and learned and becomes a source of cohesion – that is, the structure and content of practice" (ibid p. 283).

In other words, Wenger is not only concerned with the flow of information between nodes, he also emphasizes the differences in what flows across the network. Communities of practice are characterized by three related structural properties, that of a shared enterprise, mutual engagement, and a shared repertoire (Wenger 1998 p. 72 ff), while networks are characterized as interconnected nodes (Castells 1996/2000) or the *connections* between learners, learners and tutors, and between a learning community and its resources (Jones, 2004 a p.1) As such networked learning is concerned with establishing connections, and relationships whereas a learning environment based on communities of practice is concerned with the establishment of a shared practice.

In some learning environments this is dealt with as a combination of the networked perspective and community of practice, in the sense that the individual learner is supported in relating learning to his / her work practices, which are seen as the primary community of practice (Jones 2004 a). However in other learning environments, different means are used such as team based project work in order to design for, and establish true interdependencies and mutual engagement between participants (Dirckinck-Holmfeld, Sorensen, et al. 2004).

The notion of networked learning and its practical application to the design of networked learning environments resonates strongly with a relational approach and raises several questions:

- Should researchers in CSCL serve as critical opponents to the overall trends in the networked society and stand up against "networked individualism", or should the design of CSCL and education reflect these trends?
- Which models, networked models or community of practice models, are more productive with respect to the learning of the individual participant and under what conditions? Is it, for example, more productive for busy professionals to be organized through a pedagogical model based on relatively weak ties or is it more productive to be organized in a pedagogical model facilitating the development of strong ties?

Space and place in networked environments

Several authors have in recent years pointed to the need to distinguish between space and place in computer networked environments (see for example Goodyear *et al* 2001, Jamieson *et al* 2000, Ryberg and Ponti 2004). Goodyear *et al* (2001 Part 8) claim that that we should not try to design the elements that are most closely involved in learning itself. They argue that it is appropriate to try to design learning spaces (the physical learning environment, including all the artifacts which embody ‘content’) but they point out that we should expect students to customize these designed spaces to make their own ‘local habitations’ or ‘nests’ (Nardi & O’Day, 1999; Crook, 2001). More generally they argue for a distinction to be made between space, understood as a relatively stable and potentially designed environment and place, understood as contingent and locally inhabited.

The distinction between space and place is connected in significant ways to the earlier discussions of technology, affordance and networks. Participants in a computer network are simultaneously situated at a real point in time and space and displaced from that in a space configured through the network. Ryberg and Ponti (2004) are interested in the development of social context in networked environments. They comment on Lash (2001) who argues that networks are non-places.

> “Technological forms of life are disembedded, they are somehow ‘lifted out’. As lifted out, they take on increasingly less and less the characteristic of any particular place, and can be anyplace or indeed no place.… The Internet is a generic space. It is no particular space. Indeed, networks are themselves by definition lifted-out spaces.” Lash (2001 p113)

The question Ryberg and Ponti ask is:

> “If networks are non-places, with no context at all, how can we create a social context to support interaction and sociability?” Ryberg and Ponti (2004 p2)

The distinction between space and place is fundamentally rooted in the shift toward networked environments and is one example of a set of problems in which designers only have an indirect control over the intended outcomes of their design. It is also related to the notion of space as produced through interactions between individuals and institutions, rather than thinking of space as simply given. Overall we argue that the notion of space and place is a problem area that could have a major significance for CSCL and practical implications in terms of design.

Ethical Dimensions of CSCL

Collaboration is not simply a technical, pedagogic or pragmatic concern. Collaboration includes an ethical dimension both in terms of the rationale for its use and in terms of the conditions for its success. The question, ‘why collaborate?’ cannot simply be answered by measures of success such as learning outcomes or considerations of alignment with economic goals. Collaboration has an ethical dimension that speaks to the ways in which we choose to structure our social lives. Too often collaboration is reduced to narrow concerns that ignore this ethical choice. This can lead to those involved in a CSCL environment not appreciating the rationale behind activity and comparing it unfavorably with individualized and transmissive methods that flow from different ethical positions.

In terms of the considerations for the successful use of CSCL the question of trust is perhaps central. Trust has been identified as an ethical question at the heart of communication:

> “Regardless of how varied the communication between persons may be, it always involves the risk of one person daring to lay him or herself open to the other in the hope of a response. This is the essence of communication and it is the fundamental phenomenon of ethical life.”(Løgstrup, 1997, p. 17).

Rasmussen (2004) has argued from this position that this:

> “ is not a question of a concept of trust which stands or falls on whether or not it is honoured. It is a matter of the simple form of trust expressed by the fact that we cannot avoid surrendering to each other.” (Rasmussen 2004 p4)

Furthermore Rasmussen argues that this ethical demand can only be honored spontaneously. As soon as we begin to think about whether we are really acting as we ought, the focus moves away from acting exclusively in relation to the other person and towards ourselves. This ethical requirement for spontaneity can come into conflict with the demand for self-reflection. In educational terms we often require our students to be critically reflective in relation to their own work and the work of others. The question then arises as to how this might affect trust in CSCL environments. In so far as we require actions which are engaged in as a duty these actions may loose an element that is central to trust and as a consequence to collaboration. If free communication relies upon spontaneous action and the ability to lay oneself open to others how far does the planful nature of many CSCL environments and the pedagogic requirement for reflection affect collaboration and communication, and how might we design CSCL environments to reflect this ethical concern?

A second area of ethical issues affecting the conditions for productive learning arises around surveillance and control. Writers from a Foucauldian tradition point to CSCL environments as environments in which participants are aware that their actions are under surveillance (see for example Land and Bayne 2002, Rasmussen 2004). Surveillance comes from other participants in an equal power situation and often from others who are in a position of actual or potential control. Land and Bayne point out that for the tutor as constituted in the discourse and practices of computer mediated environments they are both 'seers' of their students and 'seen' by their managers in an increasing process of accountability in education. This would suggest that participants would generally conduct themselves in accordance with the perceived norms of the environment and attempt to conceal actions that step outside of the accepted norms.

An example of how issues of trust impact on learning in networked environments can be found in the work done by the moderator in networked learning environments. Salmon (2000) argues that successful learning is the result of networking, but it is crucial that networking occur within a safe space. Part of the moderator's role, according to Salmon, is the creation of this safe space, and addressing any concerns or fears that the learners may have. Trust is a central element in the provision of both a safe environment for learners and the conditions for communication and collaboration. An interesting research question for CSCL might be how the condition of trust affects different types of relationship. It is by no means obvious that the weak links identified in network analysis are any less dependant upon trust, indeed the maintenance of weak links may require a high degree of trust just as much as the strong links of community and collaboration require high degrees of trust.

FUTURE PERSPECTIVES FOR CSCL

Throughout this paper we have tried to indicate where we believe our reflections point us in terms of future topics and issues for CSCL research. Overall we have argued for a relational approach to our understanding of technology, affordances and infrastructure and we wonder if a network metaphor and an ethical dimension to our approach may be necessary. We indicated that the question of how technologies simultaneously embed constraining features, and express relatively fixed properties, including design intentions and are also brought into use contingently in ways related to and reconfigured by users with differing intentions in a variety of settings, draws us towards what we describe as a relational approach to technology and its affordances and an indirect notion of design. Technology within the CSCL tradition has had a relatively narrow focus that places in the background issues concerning the politics, policies, institutions and infrastructures in which the processes of CSCL take place. We would argue for a greater focus on what we call the meso-level of collaborative learning. We would include in this the way in which many of the aspects of the settings in which CSCL is enacted are beyond the direct control of the individuals and groups involved. We suggest that the concept of technology itself and in particular the use of the term technological artifact is an area that requires further attention in CSCL research and we point in particular to the Web and Internet as large scale and composite technological forms through and in relation to which CSCL now takes place. The past ten years have seen CSCL move on from an environment in which the Internet was a minority concern and the Web only an emerging form to a time when the Internet is becoming ubiquitous and the Web a basic platform.

Our research points us to a number of ethical questions related to our approach to technology. To how the condition of trust affects different types of relationship, including the weak links identified in network analysis and the strong links of community and collaboration. We wonder whether the designs of networked learning environments have to reflect the trend towards 'networked individualism' or whether CSCL researchers might choose to act as a counter practice by offering opportunities for the development of collaborative practices. We ask whether CSCL should privilege certain models of learning, for example networked learning or communities of practice, and whether such models are more productive with respect to learning and under what conditions that might occur. We point to the example of continuing professional development for busy professionals and wonder if organization using a pedagogical model based on relatively weak ties or one based on the strong ties in a community of practice is more appropriate. We argue that these are choices that need to be made on the basis of CSCL research, which can provide good criteria for selection.

The approach to technology outlined above points to the need for what we label indirect design so that we can design for learning. The relational view we have of technology and its affordances suggests that designers have limited direct control over how their designs are enacted. How learners respond to, understand and enact in relation to any design is a complex, structuration process which has to be studied in practice. Examples of such studies have been given throughout this paper and in our review of the case studies and theoretical work we had undertaken it became clear that there was an underlying common theme in relation to design. In order to plan and design for learning in CSCL environments some degree of predictability of response to the design is required. Our research showed how contingent factors necessarily reduced design capacity in this critical regard.

We focused on exactly what we understood to be available in terms of design as predictable aspects for planning. We suggest that designers within CSCL need to concentrate less on the material aspects of the designed artifact and more on the relationships that surround the enactment of the design and the mobilization of technologies and artifacts in that enactment. This approach might also suggest a flexible approach to design in which designed artifacts are thought of as shells, plastic forms that incline users to some uses in particular but are available to be taken up in a variety of ways and for which the enactment of preferred forms depends upon the relationships developed in relation to the design.

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Design Principles for Online Peer-Evaluation: Fostering Objectivity

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Abstract. Peer-evaluation is a powerful method for fostering learning in a variety of contexts. Yet challenges of application in contexts involving personal values received little attention. This study used a design-based research approach to explore such challenges in an undergraduate educational-philosophy course. The study was organized in three design-and-implementation iterations of a peer evaluation activity. Discrepancies between student and instructor scores were explained by bias due to non-objective student personal stands. Refinements to the design, based on emerging design principles a) assisted students to better differentiate between objective criteria and personal opinions, b) increased learning gains, and c) decreased tensions between different cultural groups.

Keywords: Online peer-evaluation, Design, Undergraduate Education, Educational Philosophy

INTRODUCTION

Peer-evaluation is an educational strategy in which students are required to evaluate the work of their peers. The evaluation can focus either on a learning product, or on the process. Many studies have shown that peer-evaluation is a powerful method for leveraging learning processes in a variety of contexts (e.g., Falchikov, 2003; McConnell, 2002; Suthers, Toth, & Weiner, 1997; Topping, 1998). Learning outcomes from peer-evaluation are related to: a) leveraging student understanding of evaluation criteria, and thus supporting students in creating improved artifacts, b) learning by reviewing peers' work, c) consideration of a wide range of feedback, and d) development of evaluation skills (Ronen and Langley, 2004; Zariski, 1996; Dominick et al., 1997; Miller, 2003). There is a debate concerning the legitimacy of using peer-evaluation scores as replacement of instructor's scores. In such cases, the outcomes of the peer-evaluation are usually validated by comparison with the instructor's evaluation (e.g., McGourty et al., 1997).

One of the main obstacles in the implementation of peer-evaluation is that it demands a great deal of management, organization and analysis work. Technology can provide powerful tools to reduce this workload, either by using generic online environments including forums and email (Mann, 1999), or by using targeted environments developed specifically for online peer-evaluation (e.g., Davies, 2000; Cuddy et al., 2001). Another obstacle of peer-evaluation is the issue of bias (Topping, 1998). Approaches that have been used to minimize bias in many cases are solved by anonymous evaluation. However, there is another aspect of bias that has received very little attention in the literature. This aspect, rather than being related to the *people* who are evaluated, is related to the *contents* that are being evaluated. When these contents are related to values, and are socially or culturally sensitive, designing peer-evaluation activities becomes a special challenge, and solutions such as anonymity are not sufficient to help students provide objective, non-biased evaluation to their peers' work. Our main goal in this research is to explore the challenges of peer-evaluation in a context in which personal values, morals and ethics are involved. An additional goal is to provide a set of design principles that immerge from this study, and apply to other contexts that involve similar challenges.

CONTEXT

This research took place in the context of a compulsory course in educational philosophy for undergraduate level at a university in Israel, taught by the first author of this paper. The main goal of the course is to help students develop their own perceptions about fundamental issues in education and schooling (e.g. what is the goal of schooling? What contents should be taught in school? What should be the role of the teacher?). In order to understand the social dynamics in the class it is important to note that the student population of compulsory courses in undergraduate level at that university is typically heterogeneous and includes about one third of

Jewish students who were born in Israel, one third of Jewish students who are relatively new immigrants from the former USSR and one third of Israeli Arab students (Moslem and Christian).

A main theme in the course is the “ideal school” project, in which groups of 3-4 students construct a conceptual model of a school that meets their evolving educational perceptions. Toward the end of the semester each group gives a short presentation of one day in their ideal school. For this purpose, most students use PowerPoint, but other less-conventional means, such as drama-performances were also used. The presentations took place in three class meetings, with three or four presentations in each session. One challenge we faced was how to ensure that students make the most out of these meetings. Prior teaching experience in similar contexts reveals that students tend to be focused on accomplishing the course’s requirements (their own presentations in this case) and less interested in their peers’ projects. This challenge was addressed by designing a peer-evaluation activity, in which students were involved in the assessment of their peers the “ideal school” presentations. The rationale for engaging students in this activity was: a) to ensure their involvement in their peers’ projects, b) to create a framework for them to learn from each others’ projects, c) to help them develop evaluation skills that they would need as future educators, and d) to reinforce criteria for building their products. The analysis of this peer-evaluation activity by the instructor involved the integration of hundreds of assessments (35 students, times 10 groups, times about four criteria). To help facilitate that analysis we decided to use a computerized system, which would enable gathering, presenting and analyzing these assessments in a productive manner. The activity was therefore performed online with the CeLS environment (Collaborative e-Leaning Structures), a novel system that allows the instructor to create and conduct a variety of online structured collaborative activities (http://www.mycels.net)

METHODS

In order to explore the challenges of peer-evaluation in this context we used a design-based research approach. Barab and Squire (2004) describe design-based research as: a) resulting in the production of theories on learning and teaching, b) interventionist, and involving some sort of design, c) takes place in naturalistic contexts, and d) iterative. In this spirit, the study was organized around three design-and-implementation iterations that took place in successive semesters with a total of 144 students (Iteration 1: fall 2003 with 80 students in two groups; Iteration 2: spring 2004 with 29 students; Iteration 3: fall 2004 with 35students). Each iteration was followed by data analysis and refinements to the design of the online peer-evaluation activity. Data-sources included:

- Peer-evaluation data (numeric grades and textual explanations) gathered in the CeLS environment.
- Artifacts created by each group (PowerPoint slides of the “ideal school” project and online discussions used by each of the groups for developing the conceptions for their project).
- Students’ responses to an attitude questionnaire administered at the end of the course.
- Students’ spontaneous online discussions in a virtual “coffee corner” at the course’s site.
- Instructor’s reflective journal including remarks about the events that took place during class.

The outcomes from each iteration were defined as Design Principles, according to a framework defined in the Design Principles Database (http://design-principles.org). This database is a public infrastructure funded by the National Science Foundation (NSF) and developed by the Technology Enhanced Learning in Science (TELS) center. One of the main goals in the database is to enable designers to build on the successes and failures of others rather than reinventing solutions that others have struggled to develop (Kali et al., 2004).

THE EVOLUTION OF THE DESIGN

First iteration: Initial design

The initial online peer-evaluation activity was designed according to the following design principles that were abstracted from the literature concerning peer-evaluation:

Design Principle 1: Involve students in the development of evaluation criteria
Design Principle 2: Make evaluation anonymous as possible
Design Principle 3: Use an overall global score rather than scoring individual dimensions
Design Principle 4: Use scores generated from the peer-evaluation only after validation
Design Principle 5: Minimize workload for instructors

The initial design of the peer-evaluation activity included criteria that were derived from students’ suggestions in a classroom discussion that occurred prior to the presentations and included the following: a) is the uniqueness of the school apparent? b) is the rationale clear? c) are the activities that take place in the school demonstrated clearly? The activity included an online form in which students were required to grade each of the group-presentations between 1 (poor) to 7 (excellent). The form also included text fields for students to justify their grading according to the three criteria. Students used prints of these forms to take notes during the presentations, and entered their grades and justifications to the online environment in the next few days. At the end of the activity all students were able to view a histogram of the scores for each group, statistical data (sample size, mean, median, and standard deviation), and the individual scores and the justifications for each score (presented anonymously) (figure 1). All this information was automatically generated by the CeLS environment without requiring any extra work of the instructor.

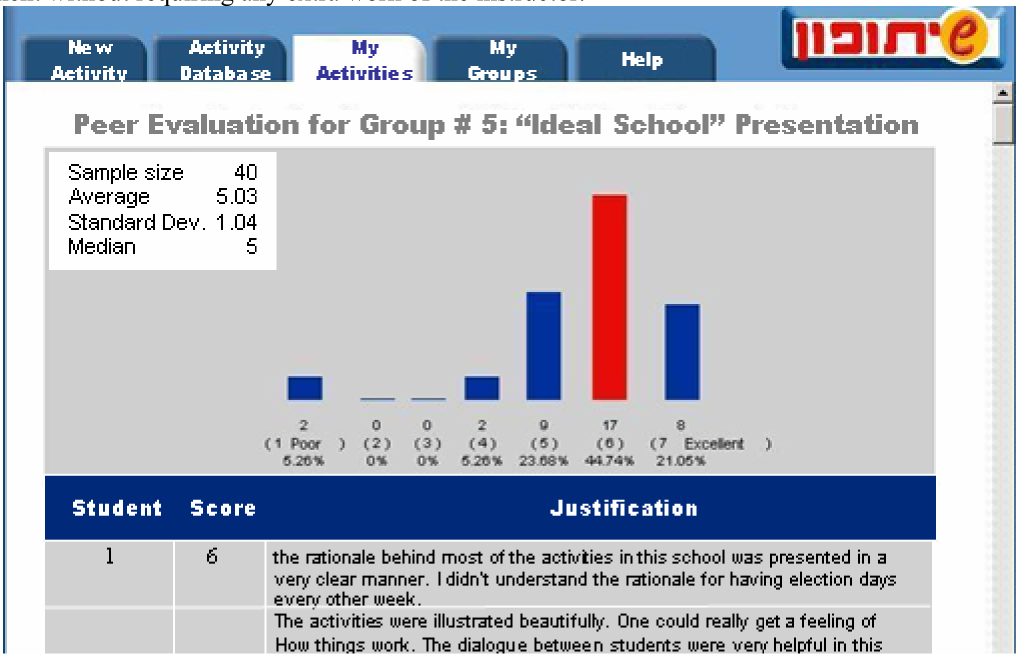

Figure 1: Interface of the peer-evaluation activity in the CeLS environment

In order to assess the validity of student scoring, the set of mean scores that were given by students for each of the 10 presentations was compared with the set of scores given by the instructor for these presentations. We refer to the instructor's grading as standard reference, and used it to validate students' grading (as in Falchikov & Goldfinch, 2000). The analysis indicated that though there was a moderate positive correlation between students' scores and the instructor's scores (r=0.43), it was not significant (p=0.1). A detailed examination of the qualitative data enabled us to identify the cases in which large discrepancies were found between students and instructor's scoring. Such discrepancies were especially apparent in presentations that introduced educational perceptions that were relatively "extreme" according to views held by many students. Though students were specifically instructed to try to ignore personal viewpoints in their grading, it seems that they found it difficult to so. An example can be seen in Figure 2. The "ideal school" presented by Group #2 was based on a somewhat existentialistic rationale; elementary students were entitled to have many choices, including the choice not to participate in any lesson. According to data analyzed from the course's online discussions, and from ideas presented in other groups' projects, most students' perceptions about schooling were more conservative. Comparison of the scores provided by the instructor, and those provided by students, shows that the largest difference was found in the scores for this presentation. The justifications that some of the students gave for lower scores, indicate that their scoring for Group #2 was biased due to their objection to the educational perception presented. For example, one student justified a low grade by saying "…students are too young at this stage and shouldn't be given such responsibilities…" Other students justified low grades by using the supposedly objective criteria, but in a biased manner. Justifications such as "the rationale wasn't at all clear" or "the activities that take place in the school weren't explained well", which were in complete contradiction with the view of the instructor and the other students, indicate that they were probably biased. In order to use the scores generated by students for grading their "ideal school" projects (15% of the final score in the course), scores that seemed biased were omitted from the statistics.

Second iteration: Differentiating between objective criteria and personal stands

Based on the outcomes of the first iteration, and in order to foster objectivity, we decided to refine the design of the online peer-evaluation activity so that it would provide students with a way to differentiate between objective aspects of the presentation and their personal, non-objective viewpoints. Our rationale was that if students would be given a chance to express these views in a neutral area, which does not affect the score, they would be more aware of their personal values and emotional stands, and thus, provide a more objective score. Therefore, we defined the following design principle and added it to the Design Principles Database:

Principle 6: Enable students to state their personal, non-objective viewpoints about their peers' work.

As in the first iteration, a class discussion about evaluation criteria preceded the activity. To engage students with the issue of personal viewpoints in peer-evaluation, we decided to seed the class-discussion with ideas for criteria, including a criterion about the degree to which a student is in agreement with views introduced in the presentation. Following the classroom discussion, four text areas for justifying scores were defined. The first three were similar to those defined in the first iteration (referring to uniqueness of the school, rationale, and demonstration of activities), but a forth area to was added, named "My personal opinion about this school". As suggested by students, this field was *not* considered a criterion that should effect scoring. Rather, it was intended to provide general feedback for presenters as to the degree of acceptance of their ideas among other students. Another design principle was therefore added it to the Design Principles Database:

Principle 7: Foster discussion about non-objective evaluation criteria

Outcomes indicate that the refined design, which enabled students to express their personal viewpoints, assisted students to better differentiate between objective criteria and personal stands. This was evident from a higher correlation between the set of scores provided by the instructor for each of the groups, and those provided by students ($r=0.62$, $p=0.03$) compared to the first iteration. Furthermore, the learning gains from the peer-evaluation activity, as indicated from the attitude questionnaire, seemed to be higher in the second iteration. This can be seen in a comparison between answers to a question regarding the extent to which students felt that the peer-evaluation activity contributed to their learning (Figure 3).

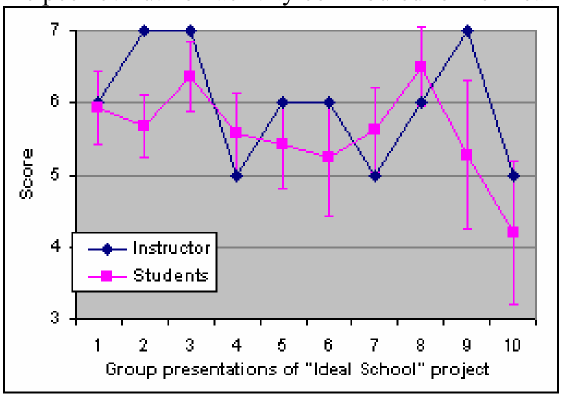

Figure 2: Comparison between scores provided by instructor and by students for each of the groups.

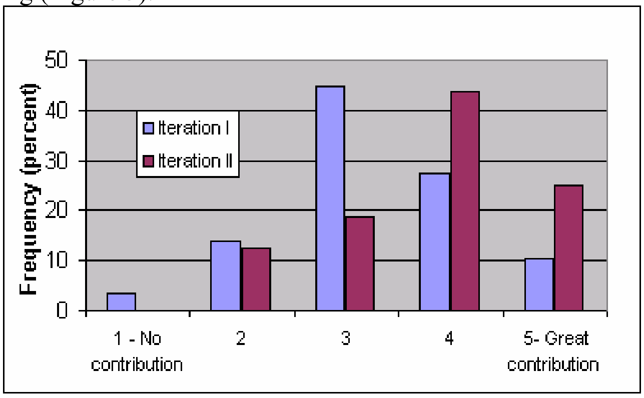

Figure 3:Distribution of student responses concerning the degree to which the activity contributed to their learning.

However, further revisions for the activity were suggested following an incident that occurred during the peer-evaluation of a certain group's presentation. The main rationale for the "ideal school" presented by that group was to bridge between religious and non-religious students in a certain cultural group. At the end of the presentation, a discussion was held between students as to whether such a school could be applied to bridging between other religious and non-religious groups. The presenters claimed that the problems that they dealt with in their school were unique. This answer, in the context of a complicated political situation in Israel, created tension in the discussion, which eventually found its way to the peer-evaluation activity, as inappropriate and even offending justifications, and biased scoring provided from a few of the students in the evaluation for that group. Following this incident, a spontaneous online discussion took place between several students and the instructor at the "coffee corner" of the course's site. In their postings, all students, no matter which sector they represented, were empathetic toward the presenters of the project, praised the quality of their presentation and criticized the biased scores and offensive justifications. They also questioned the appropriateness of the peer-evaluation activity, and discussed ideas for changing it. Students seemed to agree that the learning outcomes were tremendous, but did not like the fact that other students, who might be biased, might affect their final grade for the course. It is important to note that except for this event, the multi-cultural characteristic of the student population provided a source of richness to discussions, and to "ideal school" projects. Several of the groups were mixed (by their own choice), and introduced conceptions that fostered highly tolerant ideas.

Third iteration: Evaluating students as evaluators

Based on the findings of the second iteration, and in order to further foster objectivity, classroom norms, and tolerance, we designed the third iteration of the activity according to the following design principles.

Principle 8: Do not grade students according to peer-evaluation results.

Principle 9: Evaluate students as evaluators using results from peer-evaluation.

According to these principles, 15% of students' scores in semester fall 2000 were derived from the peer-evaluation activity and indicated how well they served as evaluators. The score was comprised of: a) number of evaluations provided, b) respecting classroom pre-defined norms, c) quality of justifications, and d) degree of correlation with instructor's score. Outcomes indicate that implementation of the redesigned activity enabled students to better exploit the vast advantages of peer-evaluation; tensions were decreased, and higher correlation with instructor ($r=0.7$, $p=0.02$) were found.

SUMMARY

This study builds on the body of knowledge created by many studies that have designed, applied and analyzed peer-evaluation activities in a variety of contexts. We translated this knowledge into design principles and used them for designing a peer-evaluation activity for an undergraduate educational-philosophy course, taught to a multi-cultural population. Implementation in three iterations, careful analysis and tailoring of the design in a design-based research approach, enabled us to identify and confront challenges in peer-evaluation, which arouse when the evaluated contents involve personal non-objective values and morals. The following design principles emerged from this study, and apply to peer-evaluation in such contexts: a) enable students to state their personal, non-objective viewpoints about their peers' work, b) foster discussion about non-objective evaluation criteria, c) do not grade students according to peer-evaluation results, and d) evaluate students as evaluators using results from peer-evaluation. These design principles were contributed to a public online resource, the Design Principles Database, for further enhancement of the design field.

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Problem Solving as a Complex, Evolutionary Activity: A Methodological Framework for Analyzing Problem-Solving Processes in a Computer-Supported Collaborative Environment

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Abstract. Viewed through the lens of complex systems science, one may conceptualize problem-solving interactions among multiple actors, artifacts, tools, and environmental structures as goal-seeking adaptations, and problem-solving itself, as a complex adaptive activity. Theories of biological evolution point to an analogical equivalence between problem solving and evolutionary processes and, thus, introduce innovative methodological tools to the analysis of computer-supported, collaborative, problem-solving processes. In this paper, we present a methodological framework for characterizing and analyzing these processes. We describe four measures that characterize genetic evolution - *number*, *function*, *fitness*, and *persistence* - to characterize the process of collaborative problem solving, and instantiate them in a study of problem-solving interactions of collaborative groups in an online, synchronous environment. Issues relating to reliability, validity, usefulness, and limitations of the proposed methodology are discussed.

Keywords: Problem solving, complex adaptive activity, convergence, fitness, persistence

INTRODUCTION

In this paper, we present a quantitative, analytical method for characterizing and analyzing the process of computer-supported, collaborative problem solving. Underpinning our work is a shared, situative, epistemological belief that learning in general, and problem solving in particular, is a continuous, dynamic process distributed in space and time over multiple actors, actions and artifacts, influencing and being influenced by the environment in a complex, adaptive, and iterative manner. As such, understanding the *process* of how multiple actors, artifacts, and environments interact and evolve in space and time on the way to an outcome ranks among the most important challenges facing educational research (Akhras & Self, 2000; Barab, Hay, & Yamagata-Lunch, 2001), and measures and methods for tracking the evolution of problem-solving processes as well as the emergence of learning are needed (Barab et al., 2001; Barron, 2003; Collazos, Guerrero, Pino, & Ochoa, 2002; Collazos, Guerrero, Pino, & Ochoa, 2004; Derry, Gance, Gance, & Schlager, 2000). Complex systems science is put forth as a framework for understanding the evolutionary dynamics of problem-solving processes and outcomes. From there, we derive a set of micro-genetic variables - *number*, *function*, *fitness*, and *persistence* - for characterizing the problem solving process, including how one might measure these variables. We situate our discussion and illustration of the proposed measures in a study of problem-solving interactions of collaborative groups in an online, synchronous environment. Finally, we discuss issues of reliability, validity, usefulness, and limitations of the proposed methodology.

THE NEED FOR A RECONCEPTUALIZATION

Despite the obvious complexity of problem-solving processes, existing problem-solving models remain linear, relatively rigid, and limited in scope for they are unable to account for multiple, dynamically changing actors, contexts, outcomes, and processes. For example, the General Problem Solver (Newell & Simon, 1972) specifies understanding and search processes as the two sets of thinking processes associated with problem solving. Here, "understanding" involves procedural knowledge, or an algorithm for solving a problem; "search" involves a means-ends analysis, or the selection of means (routine or subroutine in the algorithm) that will take one closer to the desired end (the ultimate or intermediate goal). A second example is the IDEAL problem solver (Bransford & Stein, 1993), which describes problem solving as a process involving several phases: *Identify* potential problems, *Define* and represent the problem, *Explore* possible strategies, *Act* on those strategies, and

Look back and evaluate the effect of those activities. Another example is STAR.Legacy (Software Technology for Action and Reflection) (Schwartz, Lin, Brophy, & Bransford, 1999), which also makes use of explicit inquiry cycles to describe problem-solving processes. The STAR.Legacy software shell separates and organizes complex problem-solving activities as cyclical sub-activities in attempting to help teachers and students manage complexity, guiding problem-solvers to begin with a challenge, generate initial ideas, consult experts, study resources, pilot-test, revise, and publish outcomes.

While the above and similar problem-solving models and cycles are descriptively very useful, they are limited because they tend to treat problem solving as either linear or cyclical in an effort to articulate a generalizable problem-solving process. However, problem solving is not a uniform, step-wise activity; problems vary in content and context (Jonassen, 2000). More significantly, these problem-solving models and cycles assume that their problem-solving processes are differentially applied in different contexts and situations but do not indicate exactly *how* that occurs.

An ability to account for the varying contexts and situations is somewhat offered by the prevailing socio-cultural, constructivist theories such as Activity Theory (AT) (Leont'ev, 1978). This is evident in their popular and persistent use by many researchers as a framework for understanding collaborative/collective activity. AT, for instance, provides the inclusiveness and plasticity needed to describe collaborative activity as a product of complex interaction among multiple actors, artifacts, and environment. As a result, working within the framework of AT, one can describe problem solving as a process of continuous change, development, and construction. One can also describe systemic structures - people, culture, and artifacts - that emerge through the process of problem solving as well as the emergent properties of interactions within those systems. Working strictly within the framework of AT though, one is not able to explain exactly *how* interactions contribute to the change, development, and emergence of structures and solutions over time. In other words, AT states that problem solving evolves over time, but not *how* it does so. As mathematical sociologist Mark Granovetter (1978) suggested in his model of collective behavior, an analysis of "norms, preferences, motives, and beliefs" (as indeed afforded by socio-cultural, constructivist theories such as AT) can account for the *necessary but not sufficient* conditions one needs in order to explain how these conditions "interact and aggregate" on the way to an outcome. We argue that taking a step towards achieving sufficiency, i.e., the theoretical and methodological tools to explain the problem-solving process and *how* it evolves in time, one requires a lateral step into complex systems science.

COMPLEX SYSTEMS SCIENCE

Complex Systems Science provides a framework for studying how interactions among the parts of any given system culminate in the behaviors of the system as a whole (Crutchfield, 1994). As a theory, complex systems science enables researchers from both the natural and social sciences to speak the same language as they study the same or similar macroscopic behaviors and interactions in a range of natural and artificial systems (Bar-Yam, 1997). As a science, complex systems science enables researchers to reason about this uncertainty, extracting measures and constructs that allow researchers to discover, describe, and predict *how* interactions form patterns, *how* patterns form complex systems, and *how* those complex systems behave (Crutchfield, 1994).

Problem Solving and Evolution: A Two-Way Analogy

According to complex systems science, adaptation is one macroscopic behavior shared across systems - biological, physical, and cognitive. A complex adaptive system (CAS) changes its behavior in response to environmental and internal feedback, often in an attempt to achieve a goal or objective (Bar-Yam, 1997). Goal-seeking adaptations that occur on a collective scale and/or over multiple iterations emerge as evolution (Bar-Yam, 1997). Modern synthesis, the prevailing theory of evolution, combines Darwin's theory of variation and natural selection with Mendel's theory of genetics to characterize evolution as a process of development or change over time. According to complex systems science, this process extends biological organisms to include the development or change of a culture, or an idea. Problem solving, too, involves iterative goal-seeking adaptations (or operations) through which an agent (or collection of agents) tries to reduce discrepancies between an initial problematic state and an ideal goal state (Newell & Simon, 1972). Thus, a group of people collaborating to solve a problem can be seen as a complex adaptive system, and evolution entails how the group interacts to solve a problem and how this interaction develops and changes over time. This facilitates a strong two-way analogy between problem solving and evolution - evolution may be characterized as a problem-solving process, and problem solving as an evolutionary process where ordered patterns move, sometimes through seemingly random paths, toward desired goals.

Measures for Characterizing the Problem Solving Process

Modern synthesis may provide useful analogies to describe what one might observe during the process of collaborative problem solving, but not what one might measure. *Cybernetics*, a field closely allied with complex systems science, provides three measures - *number*, *function*, and *fitness* of problem states - that prove informative for describing and explaining the problem solving process (Heylighen, 1988). When one imagines the collaborative problem-solving process as a sequence of problem states, the *number* of states from the initial state to the goal state can serve both as a temporal and spatial measure: temporally, each state is a *tick* on the evolutionary clock; spatially, each state is a *step* along the evolutionary path (Heylighen, 1988). In biological evolution, each mutation reconfigures the gene. Similarly, in problem solving, each interaction reconfigures the problem state. This reconfiguration may increase or decrease the difference between the reconfigured and goal states and, thus, the distance (number of *ticks* or *steps*) required to reach the goal state. Each interaction, then, has a positive (acceleratory) or negative (deceleratory) *impact* on the problem-solving process. In other words, each interaction *aims* to perform a telic function, i.e., it operates to reduce the difference between the current, problematic state and a specified goal state. Thus, one can view problem-solving interactions as *operators*, goal directed actions, performing a means-ends analysis in the problem space (Newell & Simon, 1972). However, with the exception of the initial interaction in a problem-solving episode, the configuration of a problem-state's properties results from more than one interaction; the configuration emerges from the cumulative impact of all the interactions up to that particular state. The distance between any intermediate state and the goal state reflects the cumulative impact of interactions. If problem solving means minimizing this distance between a given state and the goal (or end) state, then cumulative impact reflects the *fitness* of the collaborative problem-solving process at the given state (Heylighen, 1988).

Furthermore, another sub-domain of complex systems science - *artificial life* - provides an additional measure for characterizing the collaborative problem-solving process. In artificial life, a complex adaptive system is viewed in terms of the behavior of its constituent components. For example, in biological evolution, the components are families of genes. Analogously, in collaborative problem solving, these components can be seen as taxonomic families of interactions or functional categories. Adaptive evolution of the problem-solving process can be expected to affect the dynamics of these categories (Bedau, Snyder, & Packard, 1998) and conversely, the dynamics of these categories inform the evolutionary activity structures of the problem-solving process. The dynamics here refer to the evolutionary activity of these components, how and when they come into *existence* as well as their subsequent *usage* in the system. In other words, by using a measure of persistence one can identify the traits (functional categories) introduced by each interaction, and then track the use and usefulness of those traits. When added to fitness analyses, persistence may reveal how multiple evolutionary processes converge on similar paths without implying a single best path.

METHODOLOGY

We situate our discussion and illustration of the proposed methodology in a study of computer-supported, collaborative, problem-solving interactions. Bearing in mind that the goal of this paper is to advance a methodological framework, we briefly describe the context of the study in which the methodology was instantiated first before illustrating the process and usefulness of our methodology.

Research Context and Data Collection

Participants included sixty 11th grade students (46 male, 14 female; 16-17 years old) from the science stream of a co-educational, English-medium high school in Ghaziabad, India. They were randomized into 20 groups of three and instructed to collaborate with their group members to solve two problem scenarios. Both presented an authentic car accident scenario that required the application of Newtonian kinematics. The study was carried out in the school's computer laboratory, where group members communicated with one another only through synchronous, text-only chat. The chat application allowed groups to privately and simultaneously engage in synchronous discussions and automatically archived the transcript of their discussion as a text file. These 20 transcripts, one for each group, contained the problem-solving interactions of group members as well as the final solutions produced by the groups and formed the data used in our analyses.

Data Coding: Categorizing Problem-solving Interactions

Quantitative Content Analysis (QCA) (Chi, 1997) was used to segment and code interactions using an interaction coding scheme developed by Poole and Holmes (1995), namely the Functional Category System (FCS) (see Table 1). Two trained doctoral students independently coded the interactions; inter-rater reliability was .85.

Table 1: Functional Category System (FCS)
(Adapted from Poole & Holmes (1995), p. 104)

1. Problem Definition (PD)
1a. *Problem Analysis*: Statements that define or state the causes behind a problem
1b. *Problem Critique*: Statements that evaluate problem analysis statements
2. Orientation (OO)
2a. *Orientation*: Statements that attempt to orient or guide the group's process.
2b. *Process Reflection*: Statements that reflect on or evaluate the group's process or progress
3. Solution Development (SD)
3a. *Solution Analysis*: Statements that concern criteria for decision making or general parameters for solutions
3b. *Solution Suggestion*: Suggestions of alternatives
3c. *Solution Elaboration*: Statements that provide detail or elaborate on a previously stated alternative.
3d. *Solution Evaluation*: Statements that evaluate alternatives and give reasons, explicit or implicit, for the evaluations.
3e. *Solution Confirmation*: Statements that state the decision in its final form or ask for final group confirmation of the decision.
4. Non-Task (NT)
Statements that do not have anything to do with the decision task. They include off-topic jokes and tangents
5. Simple Agreement (SA)
6. Simple Disagreement (SDA)

Table 2: Example of categorizing statements into interaction units and assigning impact values to them

Statements *(I0201, I0202, and I0203 represent the 3 group members)*	**Code**	**Impact**
I0201 DPS > physician says it was a considerable impact	1a 3a	1 1
I0203 DPS > yes as the limit was 25km/h	1a 3a	1 1
I0201 DPS > ranging bw 20g to 25g	3b	1
I0201 DPS > his medical reports r ok	1a	1
I0202 DPS > Mr rahul might have not been able to see the truck	3a 3b	1 -1
I0201 DPS > he wasn't under the influence of alcohol or drugs	3a 3b	1 1
I0201 DPS > it might be possible but he should have restricted himself to speed limit	3c 3c	1 -1
I0201 DPS > it was a blind turn	3a	-1
I0202 DPS > car has been severely struck	3c	1
I0203 DPS > he was not able to control the car i think	3b	-1
I0201 DPS > ya this proves that the impact was pretty hard and thus he was driving fast	5 3c 3c	-1 -1 -1

The *unit of analysis* was semantically (as opposed to syntactically) defined as the function(s) that an intentional statement serves in the problem-solving process. Therefore, every intentional problem-solving statement was segmented into one or more interaction unit(s) and coded into the functional categories of the FCS (see Table 2). We illustrate this with an example from our study.

The statement "*he wasn't under the influence of alcohol or drugs*" (highlighted in Table 2) was made by a participant during an interaction within a problem-solving group discussing a scenario involving a car accident. It serves two functions in the problem-solving process – first, it suggests a new parameter or criteria (intoxication, which had not been previously mentioned) for consideration in the solution and second, it asserts that the person being referred to (the driver in the problem scenario) was not intoxicated. Thus, despite being a single statement within an interaction, it contributes two units of analysis (hereafter referred to as interaction units) to two different functional categories. On the other hand, the statement "*he was not able to control the* *car I think*" serves the sole purpose of suggesting a possible factor in the solution to the problem. Hence, this statement contributed only one interaction unit. Therefore, by allowing statements to be coded into multiple interaction units, *atomicity* was achieved for the unit of analysis, i.e., interaction units can not be further divided into finer units. This, in turn, strengthens the choice of the unit of analysis (Barab et al., 2001). Bransford & Nitsch (1978) support the case for semantically-defined units by arguing that to fully comprehend a given interaction one must not only understand its words and the sentences (syntactic features), but also how it is situated in a discussion context. Chi (1997) further argued that it is often more meaningful to employ a semantic scheme, especially if it also provides for a greater correspondence between the grain size of the unit of analysis and the research questions of the study. Furthermore, recall that from the perspective of complex systems science, each interaction unit is a *functional operator* that reconfigures the problem state. Therefore, defining the unit of analysis as the *function(s)* that an intentional statement serves provides further logical correspondence with the theoretical lens used to conceptualize problem solving.

The result of coding the problem-solving interactions was a representation of each problem-solving discussion as a time-ordered sequence of functional categories or codes. Table 2 illustrates this sequence for a small sample of the coded interactions. We are now ready to describe and illustrate convergence, fitness, and persistence as measures for characterizing and analyzing the problem-solving process.

Convergence & Fitness

Convergence of problem-solving interactions may be broadly defined as the extent to which the group discussion leads to a solution as perceived by the group. To model the telic aim of problem-solving interactions and develop a measure for convergence, a two-state Markov model was used (Ross, 1996). An *a posteriori* impact value of 1, -1, or 0 was assigned to each interaction unit depending upon whether it pushed the group discussion towards (impact = 1) or away (impact = -1) from the goal of the activity - a solution state of the given problem, or maintained the status quo (impact = 0). This was done with an inter-rater reliability of .93 (see Table 2 for an example). More formally, let the problem space be defined by *n* interaction units; each assigned an impact value of 1, -1, or 0. Further, let n_1, n_{-1}, and n_0 denote the number of interaction units assigned the impact values 1, -1, and 0 respectively such that $n_1 + n_{-1} + n_0 = n$. Then convergence, $C(n)$, may be defined as:

$$C(n) = \frac{n_1 - n_{-1}}{n_1 + n_{-1}}$$

The number of zeros is not factored into the calculation of convergence. This is because interaction units assigned a zero impact, by definition, maintain the convergence level of the discussion. It is easy to see that the convergence value will always lie between -1 and 1. The closer the value is to 1, the higher is the convergence, and the closer the group is to reaching an ideal solution to the problem.

Note that the numerator in the formulation of $C(n)$ is a measure of position, $P(n) = n_1 - n_{-1}$. In other words, if the problem-solving process is a sequence of steps along a straight line - some forward (impact = 1) and others backward (impact = -1) - then the difference between the total number of forward and backward steps gives the position relative to (or distance from) the starting point, i.e., the start of the discussion. Convergence then is the mean distance from the starting point.

Convergence can also be conceptualized as measure of *fitness* of the entire discussion: the higher the convergence, the higher the fitness of the discussion. Extending this conceptualization to all problem states and not just the final one, we can define fitness as the temporal measure of convergence, i.e., at any point in time in the discussion, how close a group is to reaching the goal state – an ideal solution to the problem. Therefore, the fitness statistic at an arbitrary point in time in the problem-solving process is defined as the convergence value up to the interaction unit at that point in time, with the final fitness level of the entire problem-solving process being the convergence value itself. Recalling that time refers to *ticks* on the evolutionary clock (i.e. an arbitrary time *t* corresponds to, say, the i^{th} interaction unit), the fitness $F(t)$ at time *t* in the discussion may be defined as:

$$F(t) = C(t) = \frac{n_1(t) - n_{-1}(t)}{n_1(t) + n_{-1}(t)}$$

where $n_1(t)$ and $n_{-1}(t)$ represents the number of interaction units coded as 1 and -1 respectively, up to and including the i^{th} interaction unit. Plotting the fitness value on the vertical axis and time (as defined in this study) on the horizontal axis, one will get a representation (also called the fitness curve) of the problem-solving process as it evolves in time. Figures 1 and 2, drawn to the same scale, present four major types of fitness curves that emerged from the 20 problem-solving discussions in our study.

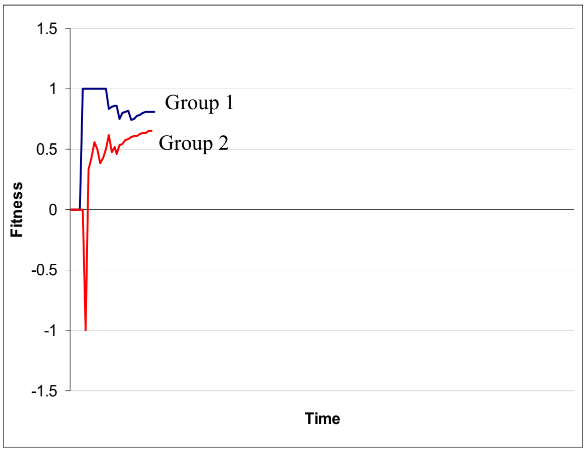

Figure 1. Fitness curves of two short discussions

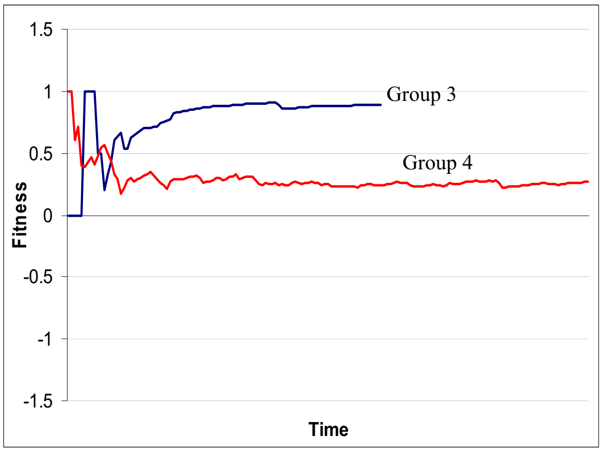

Figure 2. Fitness curves of two long discussions

Interpreting Fitness

In our view, there are five aspects to interpreting the fitness analysis. First, because the fitness value at a given time indicates proximity to an ideal solution (with higher values indicating closer proximity), fitness curves that trend upwards indicate problem-solving processes that are getting closer to an ideal solution (fitness = 1), and vice versa. Hence, fitness curves provide a quick snapshot of the entire problem-solving process in terms of how short or long it was as well as how close or far the discussion was from an ideal solution at any given point in time.

Second, the shape of the fitness curve is informative about the paths respective groups take toward problem solution. For example, groups 1 and 2 converged at approximately the same fitness levels (about 0.65, indicating positive movement toward an ideal solution), but their paths to this point were quite different. Group 1's discussion moved toward an ideal solution immediately when compared to group 2, whose initial approach seemingly took them away from the goal (indicated by the negative fitness initially) only to recover later. Similarly, comparing groups 3 and 4, we can see them settling into different plateaus of fitness albeit after some chaos (fluctuations in fitness levels) initially. Further, comparing groups 1 and 2 with groups 3 and 4, we can see that the discussions of groups 1 and 2 ended quickly whereas those of groups 3 and 4 settled into an "equilibrium" after the initial fluctuations. What is most interesting is that this interpretation of fitness curves provides a view of paths to a solution that are lost in analysis systems that consider only a given point in the solution process, thus assuming that similar behaviors or states at a given point are arrived at in similar ways. As different paths can lead to similar results, unidimensional analyses that consider only single points in time (often only the solution state) are not consistent with what we know about problem-solving processes and are not informative about movement toward a goal.

Third, the fitness curve of groups 3 and 4 also highlight the notion of "fitness inertia," i.e., having settled into fitness equilibrium, these groups found it difficult to move in new directions. Of course, group 3 did not have a need to do so, as their high fitness value indicates movement toward an ideal solution. But implications of fitness inertia for groups that equilibrate at low fitness levels indicating no or very little movement toward higher fitness levels, such as what occurred with group 4, are grave. It follows from this that the eventual performance of groups exhibiting fitness inertia can be predicted early on in the discussion. Because our analyses showed convergence (and not the position) to be a significant predictor of group solution quality ($F = 50.245$, $p = .000$), it preliminarily suggests that the net number of positive steps (the position) is not as critical to the success of a discussion ($F = 0.012$, $p = .915$) as convergence is. This can be explained by the mathematical property a ratio, which is how convergence is operationalized, i.e., it is more sensitive to initial steps, both positive and negative, than steps that are taken later on in the process. Said another way, "good" contributions made earlier in a group discussion potentially do more good than if they were made later. Similarly, "bad" ones potentially do greater harm if they come earlier than later in the discussion. Hence, convergence takes into account not only the number of positive and negative steps (contributions), but also the order in which they are taken. This temporal order is perhaps what is missing in many studies of collaborative problem solving, which typically focus on the number of steps - both positive (such as frequency counts of higher-order thinking, questioning, etc.) and negative (such as frequency counts of errors, misconceptions, lack of cooperation, etc.) - as indicators of the quality of the discussion. Because convergence takes into account of both the number as well as the temporal order of the units of analyses, it utilizes greater amount of information present in the data, making it inherently a more powerful measure - both conceptually and statistically. Hence, as indeed our results preliminarily indicate, connections to learning and problem solving as evidenced by group solution quality are stronger when seen through the measure of convergence than through frequency measures commonly used in computer-supported collaborative learning (CSCL) research.

Fourth, the end-point of the fitness curve represents the final fitness level or convergence of the discussion. From this, the extent to which of a group was able to solve the problem can be deduced. In other words, we can deduce that, comparatively, group 3 did the best followed by group 1, group 2, and finally group 4. Furthermore, the final fitness levels can also be compared with the maximum fitness level of 1. One might imagine that an ideal fitness curve is one that has all the pushes in the right direction, i.e., a horizontal straight line with fitness equaling 1. However, the data suggests that, in reality, some level of divergence of ideas may in fact be a good thing. Note that, at present, one can only extract a comparison either between groups or with the upper and lower bounds of fitness (1 or -1). But, with repeated application in other research contexts and settings and over multiple studies, norms for absolute values of convergence and fitness will begin to emerge.

Finally, based on the above analysis of the characteristics of fitness curves and what they tell us about the problem-solving process, we can begin to conceptualize how collaborative, problem-solving discussions may be scaffolded to achieve optimal outcomes. For example, the fitness curves of groups 2 and 4 suggest a need for scaffolding early on in the discussion.

Persistence

In addition to looking at the fitness characteristics of a discussion as a whole, one can also examine how ideas or families of ideas emerge and persist during the course of the problem-solving discussion. In our study, these families of ideas are represented by the 6 major functional categories - problem definition, orientation, solution development, non-task, simple agreement, and simple disagreement (see Table 1) – into which all interactions were categorized. Treating each functional category as a component of the problem-solving system, its *usage* (or *persistence*) can be tracked as a measure of evolutionary activity. The central assumption is that components of a complex system that persist and continue to be used make greater contribution to the system. However, nothing is implied about the quality of that contribution. Equivalently, functional categories that persist and get used repeatedly make greater contribution to the collaborative, problem-solving activity. Therefore, it makes sense to choose these taxonomic functional categories as components because adaptive evolution of the problem-solving process can be expected to affect the dynamics of these categories and conversely, the dynamics of these categories inform the evolutionary activity structures of the problem-solving process (Bedau et al., 1998). Having established functional categories as the components of the problem-solving system, their contribution can be measured by their usage; the idea being that the longer a functional category persists in a system, the greater its adaptive value,. Conversely, by examining the persistence of functional categories, we can gain insights into the problem-solving process that would otherwise remain elusive. More formally, let $f_k(t)$ denote whether the k^{th} functional category exists in the problem-solving system at time t:

$$f_k(t) = \begin{cases} 1 & \text{if component } k \text{ exists at time } t \\ 0 & \text{otherwise} \end{cases}$$

$f_k(t)$ is simply an *activity indicator function* that "switches on" each time an interaction unit belonging to a particular functional category exists in the discussion. In order to measure the usage of a functional category, we can define a corresponding function – an *activity incrementation function* – that increases by 1 each time the indicator function "switches on." Then, the value of the incrementation function for the k^{th} functional category at time t, say $a_k(t)$, reflects its cumulative *usage* up until time t, i.e., the persistence of the functional category up until time t. Formally,

$$a_k(t) = \sum_{0}^{t} f_k(t)$$

Figure 3 shows the persistence curve of the problem definition and solution development functional categories for two groups. We decided to illustrate persistence using these two categories because they had the most manifest interactions compared to the other four categories.

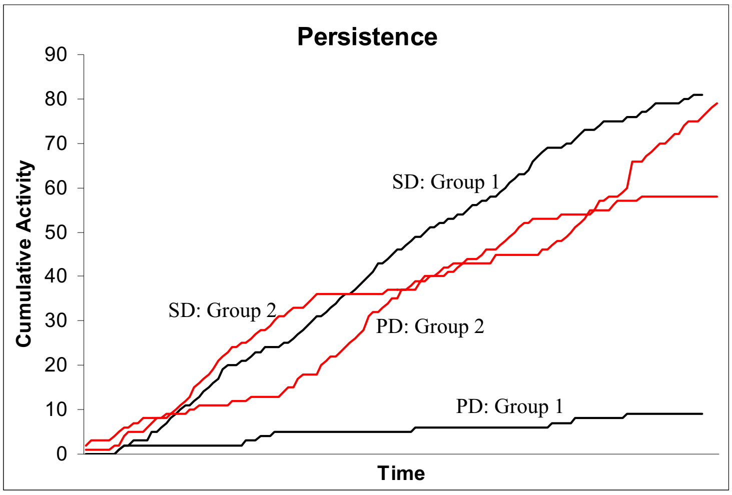

Figure 3. Persistence curves of Problem Definition (PD) & Solution Development (SD) functional categories

Interpreting Persistence

First, being a cumulative function, it is a non-decreasing curve whose end-point indicates the total activity in a given functional category, i.e., the number of interaction units in that functional category. Often, it is this number that is used as a frequency measure in quantitative content analysis. However, the number alone does not indicate anything about the evolutionary activity of the functional category it represents because, as argued earlier, it does not utilize the temporal information embedded in the data. Persistence curves utilize that information and provide a trajectory from which meaningful insights may be drawn.

Second, a plateau on the persistence curve of a functional category indicates a period in a discussion where no interactions of the type that the functional category represents take place. Therefore, persistence curves that plateau often and for long periods are indicative of a passive functional category. Similarly, a persistence curve that does not plateau is indicative of an active functional category. For example, the problem definition (PD) functional category for group 1 is an example of a passive functional category whereas the PD functional category for group 2 is an active one. In other words, this suggests that group 1 either did not see the need to define the problem or was able to define it quickly and move on, whereas group 2 seemed to need much more time and discussion for problem definition. Note that, in either case, this does not indicate whether or not the problem definition was correct, which can be revealed by cross-validating persistence curves with fitness curves.

Third, persistence curves bring out the notion of competition among functional categories. For group 1, only the SD functional category is active whereas both PD and SD functional categories are active for group 2. This suggests that the problem-solving process was by and large linear for group 1: they defined the problem early on and then worked on developing a solution. There was little or no competition between the PD and SD functional categories. However, the process was quite the opposite for group 2: their attempts to define the problem and develop a solution were iterative and intermingled making the process non-linear and chaotic. There was high competition between the two functional categories. At this point, it is difficult to use the level of competition to make inferences about the quality of the discussion or the resulting solution. However, repeated application in other research contexts and settings and over multiple studies will provide greater validity for the inferences.

USEFULNESS AND LIMITATIONS

Coding Reliability and Validity

The inferences that can be drawn from the new measures are strong in so far as the coding scheme is reliable and valid. In this study, we opted to use an existing coding scheme, namely the functional category system (FCS) developed by Poole and Holmes (1995). The reasons for choosing the FCS as the interaction coding protocol for this study are:

i. The FCS was developed specifically for the purpose of studying small-group collaborative interactions in problem-solving contexts.

ii. The FCS categories are theoretically well-grounded in the cognitive and educational theories of problem solving thereby increasing their content validity.
iii. The FCS has been tried and tested in several research studies (for example, Poole & Holmes, 1995; Jonassen & Kwon, 2001) making it inherently more reliable and stable than developing an entirely new coding scheme (Gall, Borg, & Gall, 1996).
iv. From a broader perspective of research design and measurement, using a pre-existing interaction coding scheme adds to the validity of the inferences drawn from the results (Rourke & Anderson, 2004).
This gives us reason to trust the reliability and validity of our quantitative content analysis using the FCS.

Usefulness of the Methodology

A major advantage of the proposed methodology is that it takes into account temporality of the problem-solving process and extracts measures that utilize that information. As such, when compared with existing measures commonly used in CSCL research, our research suggests that the measures of convergence and persistence are potentially more powerful in characterizing and tracking the evolution of problem-solving processes and how they lead and relate to outcomes. Further, while we situated our illustration and discussion of the proposed methodology in the collaborative problem-solving efforts of science students mediated by an online, synchronous environment, the methodology can easily be applied to other settings and contexts. We argue that the proposed methodology would be applicable to the analysis of any process that is a) goal-directed, b) complex and adaptive, and c) well-manifested through rich and meaningful artifacts (which we broadly define to include not only physical behaviors, actions, and products but also conceptual artifacts such as concepts and ideas). As such, the methodology may be applied to individual or collaborative problem-solving, in domains other than physics, with other populations, in a modality other than online, synchronous chat, and using other categorization coding schemes.

Limitations

As with any new methodology, its repeated application and modification over multiple data sets is needed before strong and valid inferences about the underlying cognitive processes can be made (Rourke & Andersen, 2004). Another limitation includes the requirement of capturing rich and meaningful data in which there is ample opportunity for evolutionary structures and goal-seeking adaptations to occur. In our study, we ensured this by making the objects of the activity – the problems – rich in context. Also, we did not impose any time limit on the group discussions. While capturing the data was made easy due to the technology itself, analyzing the data was time consuming. As such, this approach is a useful analytical framework for education researchers but not for classroom teachers. However, inferences drawn by researchers while using our methodology will have meaningful implications for the classroom, especially with regard to the design and scaffolding of instruction and learning environments for problem-solving tasks.

FUTURE DIRECTIONS

As we move forward, we plan to apply the proposed methodology in other contexts and settings. From a repeated application and modification of the measures over multiple data sets will emerge indications of the validity and reliability of the proposed methodology. In turn, this will lead to fine-tuning of the measures in an iterative fashion.

Concomitantly, we also see the need for developing new measures, especially at a macroscopic level of analysis. In particular, we will focus on stable interaction phases that a discussion goes through. In other words, a problem-solving discussion can be conceptualized as a temporal sequence of phases. One can use several methods to isolate evolutionary phases, including measures of genetic entropy (Adami, Ofria, & Collier, 2000), intensity of mutation rates (Burtsev, 2003) or, in the case of problem interactions, the classification of coherent phases of interaction. Whether these phases involve genetic mutations or problem interactions, sequences of phases often alternate between stable phases, with chaotic phases interspersed throughout: these often correspond to low vs. high mutation rates, clustered vs. unclustered interactions. With the phases identified, one can calculate and predict the probabilities of moving from one phase to another using Hidden Markov Models (HMM). As a result, one may begin to understand when and why phase transitions, cascades and catastrophes (sudden mass change), as well as stable phases emerge; more importantly, one may begin to understand how the configuration of one phase may influence the likelihood of moving to any other phase. Whether one can control or temper these phases, or whether such control or temperance would prove a wise practice remains an open question which, even if only partially answered, will be a major breakthrough in characterizing and modeling the problem solving process.

Through such an endeavor, education researchers who wish to study the problem solving process will find choices among several lenses at several resolutions. With measures to analyze number, function, fitness, sequencing, and transition of states, as well as the evolutionary activity of components (functional categories), one can zoom from the micro- to macroscopic properties and behaviors of the problem-solving process.

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Our Way to Taipei - An Analysis of the First Ten Years of the CSCL Community

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Abstract. Ten years of international CSCL conferences give proper reason to reflect on the development of the CSCL community. Based on an analysis of conference proceedings, lists of participants and lists of program committee members, this paper provides insights about the development of the CSCL community in its first decade. A focus is set on the continuity of active and passive membership, the geographical distribution and the international connectivity of the community.
Contrary to our expectations, only a relatively small number of people participate continuously in the community. Concerning the geographical distribution we found that the community is increasingly international in conference participation, authors, and program committees. The international connectivity of the community is also increasing which can be seen in a growing number of citations and co-authorships across different countries. These results can serve as a basis for further cultivation of the CSCL community.

Keywords: CSCL community, community analysis, citation analysis, social network analysis.

INTRODUCTION

Since the first workshop in 1989 (Acquafredda di Maratea, Italy; documented in O'Malley (1995)) a growing number of researchers participates in the CSCL community. An international conference series started in 1995, which includes up to now six past and an upcoming conference in 2005. Because of the growing interest on the work of this community an international journal of CSCL (ijCSCL) in printed and online (www.ijCSCL.org) form was founded in 2004. In this paper we present an analysis of the CSCL community over the past ten years to provide a basis for joint reflection which could influence the communities' further development.

The CSCL community can be defined as a scientific community of practice (Kienle & Wessner, 2005). The term "*Communities of Practice*" coined by Lave and Wenger (1991) has been defined as "*groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis*" (Wenger et al., 2002, p. 4). Based on this definition a scientific community – in general as well as the CSCL community – is a community of practice with members working in a common field of research but being distributed across disciplines, organizations, cultures and geographical regions. For their exchange the members use a combination of face to face meetings and increasingly technology-mediated interaction. This results in a heterogeneous group in which members have different views on the (CSCL) community and its main players. Methods used are from a variety of disciplines and scientific cultures. Members follow or even combine practice of basic and applied research (Fischer et al., 2003). For the CSCL community, the development of a common theory which integrates the foundations of the relevant disciplines is ongoing (Stahl, 2002a; Puntambekar & Young, 2003).

In this paper we present an analysis of the CSCL community and its development over the past ten years. We are interested in whether the community coalesces or is a set of – maybe overlapping – sub communities with a special focus on internationality. In more detail, we pose the following research questions:

1. **Development**: How does active and passive membership in the community develop?
2. **Continuity**:
   a. Do members stay in the community?
   b. Are new people joining the community and becoming active members?
3. **Connection**: How do the members of the community connect over regional boundaries? Does the connectivity grow over the years?

An informal survey among participants and authors of previous CSCL conferences pointed out that the following results would be expected for the CSCL community:

1. Authors contribute to conferences on a regular basis.
2. A larger percentage of members attend most conferences; in addition there is a sound balance between recurring people and newcomers.
3. The connection over regional boundaries is growing.

This paper tries to provide an objective view on the development and continuity of the CSCL community as well as on the connections in the community. In the following, we describe the methods and data used in our analysis (section 2) and the main results concerning the research questions above (section 3). Based on the results of our analysis we identify issues for further development of the CSCL community (section 4).

METHOD AND DATA

The analysis of scientific communities often builds on bibliometric and social network approaches. Bibliometric approaches are based on the publications of a community and focus on networks of papers linked by citations. Applicable methods include citation analysis (Garfield, 1979), bibliometric coupling (Kessler, 1963) and co-citation analysis (Small, 1973). Citation analysis looks at the citations in publications and constructs networks between publications. Bibliometric coupling regards two publications are related to the extent they are both together cited in other publications. Co-citation analysis works the other way; two papers are connected to the extent they cite the same publications. Such analyses have been done for fields such as DNA (Garfield et al., 1964), Hypertext (Chen & Carr, 1999), or Information Science (White & McCain, 1998).

Social network approaches (Scott, 1991) to scientific communities are based on the members of a community and focus on networks of people linked for example by co-authorship. It utilizes measures such as connectedness, diameter, centralization and density of a community. This has been applied to a number of research fields, too (see Newmann (2004) for an overview). Social network analysis has been applied also in the CSCL community in order to measure the cohesion in collaborative learning teams (Nurmela et al., 1999; Woodruff, 1999; Cho et al., 2002; Nurmela et al., 2003; Reffay & Chanier, 2003).

Both approaches, bibliometric as well as social network analysis, are used for a formal quantitative analysis of the publications produced by a group and the relationships among publications as well as among members. Especially in academic disciplines where the importance of publication and citation are high, co-authorship and references in the publications can be seen as an indicator of how well members of a field are connected.

For the analysis of the CSCL community we combine several approaches. We perform a citation and co-authorship analysis of the artefacts in CSCL conference proceedings and analyze other sources including the lists of participants and lists of program committee members.

Data for our citation analysis was mainly gathered from the proceedings of the six CSCL conferences in 1995 1997 1999, 2001, 2002 and 2003 (Schnase et al., 1995; Hall et al., 1997; Hoadley & Roschelle, 1999; Dillenbourg et al., 2001; Stahl, 2002; Wasson et al., 2003, Wasson et al., 2003a). Additionally all program committees (CSCL 1995 – 2005) and all available lists of participation (CSCL 1999, 2001, 2002 and 2003) were analyzed. All together we included 692 artifacts (e.g. poster, papers), 125 program committee members (PC members; PCM), 1187 authors and 1462 conference participants in our analysis. PC members, authors and participants together form members of the community. For all members of the CSCL community we recorded the following data:

- **Name**
- **Country and continent**. This data enables us to analyse the distribution of the community.
- **Conference in which she/he participated** as member of the program committee, as author, or as conference participant. On basis of this data we analysed the continuity of the community and transitions between the different degrees of participation.

In addition, we recorded the **discipline** for some participants. Unfortunately, a web search did not provide sufficient answers for most members of the community.

While recording the data we took change of name, typos etc. into account if we could detect or knew about them. The lists of participation we got from the conference organizers were not exhaustive as participants registering on site of the conferences were not included.

For a further analysis of the authors, we recorded for each author contributing to at least three conferences the following data:

- **Co-authors** for the analysis of (strong) interaction between the participants of the community
- **Referenced authors** for the analysis of (weak) interaction between the participants. From the citations of each artifact we picked those people who participated at least once as an author.

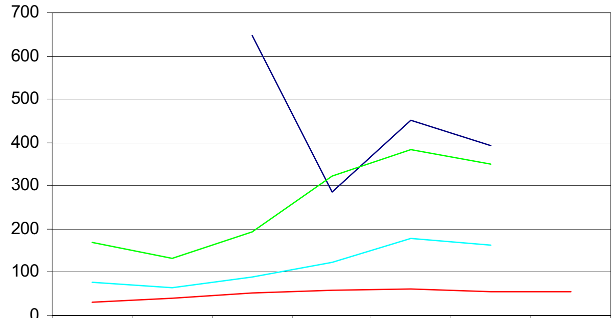
To analyze the data concerning the three research questions we carry out the following steps:

- **Development**: For each conference we analyze the absolute number of participants, authors and PC members. For the authors and PC members we also analyze the regional distribution. The comparison of the data for each year enables us to characterize the development of the community.
- **Continuity**: For each author/PCM and conference we analyze if she/he participates for the first or a repeated time. This enables us to show for each conference the number of new and recurring members. The comparison enables us to assess the continuity of the CSCL community. For each member we evaluate at how many conferences she/he participated.
- **Connections in the community**: We take those connections between members of the community into account which can be found in the artifacts printed in the proceedings. These are references as a weak connection and co-authorships as a strong connection. The focus on artifacts is justified because the artifacts represent a major part of what is communicated during the conference and between conferences - as a community memory for its members and as a source for new people joining the community. These artifacts are considered highly valuable to the community by the community itself (via the review process) and serve as a basis for communication in the community. As we are interested in the connections in the community we focus on references to authors inside the community. For co-authorship we limit our analysis to the more active authors, contributing to three ore more conferences.

RESULTS

Development of the community

Figure 1 shows the absolute numbers of community members in three groups: (conference) participants, authors, and PC members as well as the number of artifacts for each conference. The number of authors as well as the number of artifacts increases over the years. The number of PC members seems to stabilize around a value of 50-60. However, the conferences in Europe (2001 and 2003) attracted fewer participants than conferences in North America (1995, 1997, 1999 and 2002).



Year	1995	1997	1999	2001	2002	2003	2005
Participants			648	284	452	392	
Authors	170	131	192	322	385	351	
PCMs	31	40	51	57	62	55	56
Artifacts	76	64	89	124	177	162	

Figure 1: Number of community members and artifacts

Concerning the regional distributions of the conferences we focus on authors and PC members as active members of the community. As the granularity of analysis we selected continents. In figure 2 we see at the left side the composition of authors at the six past CSCL conferences. Participation of European authors was strongest in those years where the conference took place in Europe. Participation of North American authors was strongest in the all other years where the conference took place in North America. Interestingly, following the first conference in Europe (2001) the share of European authors increased also in the following conference (2002) in North America. This means that a small but substantial percentage of the authors not only enter the community when the conference is located nearby but stay from there on for a while in the community, i.e. continue to participate in following conferences.

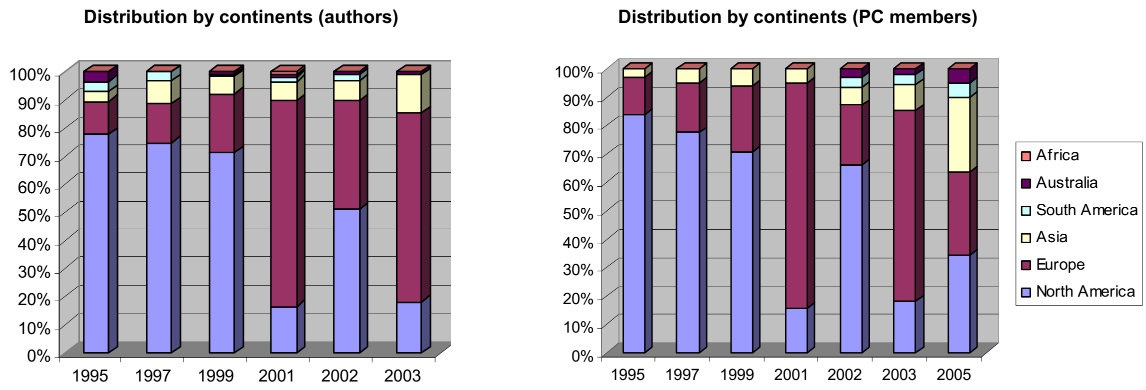
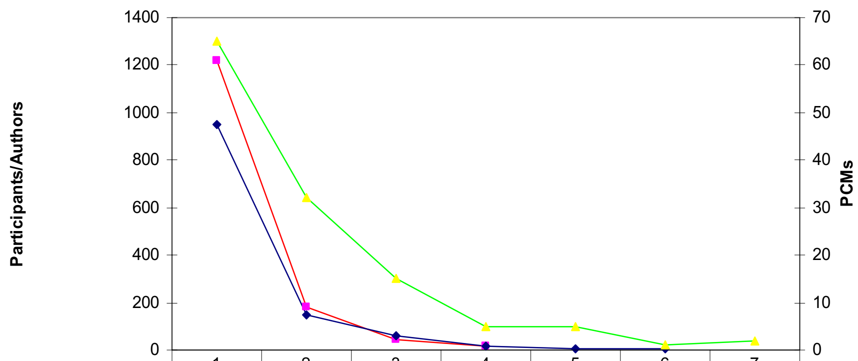


Figure 2: Distribution of authors and PC members by continents

The distribution of authors a is quite similar to the geographical distribution of the PC (see right side of figure 2). The similarity can be explained by rotation of meeting places and international composition of program committees. A study concerning the International Conference of the Learning Sciences (ICLS) shows the same relation in a different direction: No rotation of meeting places and program committees with members mainly from one country corresponds with a low degree of internationality in the group of authors (Kirby et al., in press).

Continuity

In order to assess the continuity we look at all three groups: participants, authors and PC members and at the number of conferences in which they were involved (see figure 3). In each of these groups we found different degrees of participation, taking the number of conferences in which the community members were involved as a measure. Surprisingly, about 80% of all authors contributed only to one conference. About 20% of all authors contributed to at least two conferences, and only 7.4% of authors (88 out of 1187) contributed to at least half of all passed conferences (three or more). The distribution of PC members point into the same direction but shows more continuity for this group: 50% of all PC members were involved in only one conference. As we have participation data for four conferences only, the percentages for participants are not fully comparable to the other two groups. But we see a similar distribution here: 68.5% of participants attend only one conference and only 15 persons were present at each of the last four conferences.



No. of conferences	1	2	3	4	5	6	7
Participants	1221	183	43	15			
Authors	949	150	61	19	5	3	
PCMs	65	32	15	5	5	1	2

Figure 3: Distribution of participants in three groups

Based on these findings we started a first deeper analysis which shows the quotient of new and recurring authors and PC members for each conference. The results are shown in figure 4. For both groups – authors and PC members – the absolute number and the quotient seem to stabilize. For the PC members, the absolute number is around 50 – 60, the number of new PC members at around 20 (or 33% of all PC members for a given year). For the group of authors, the absolute number is around 350-400, the number of new authors at around 230-250 (or 66 % of all authors of a given year). This indicates for both groups a relatively stable quotient of "old boys" who know and represent the existing ideas of the community and "newcomers" who bring new ideas to the group. However, the part of newcomers in the group of authors is higher than in the group of PC members.

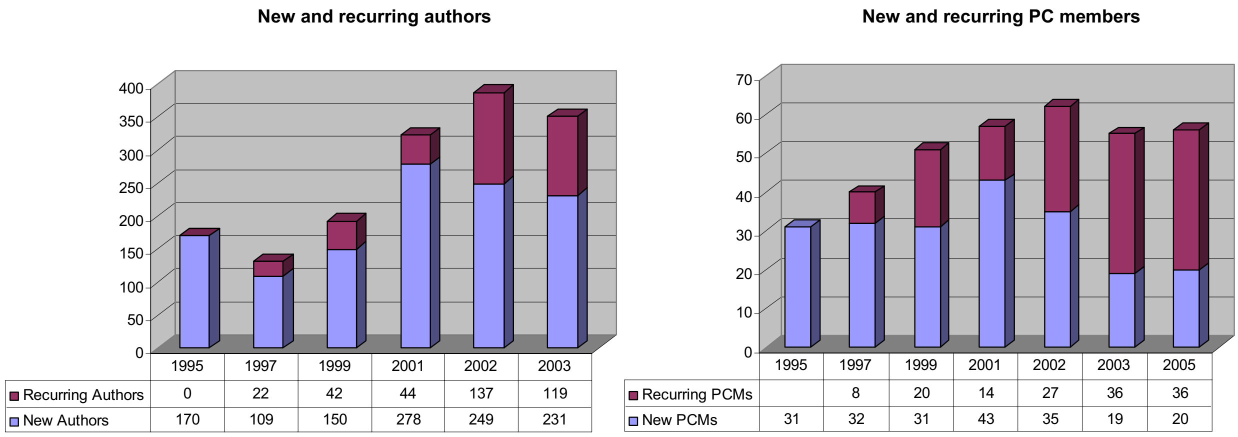


Figure 4: New and recurring authors and PC members for each conference

A second deeper analysis concerns the "key player" of the community: we take a closer look on those members who participated as authors or PC members in three or more conferences. Table 1 lists those authors and PC members who participated in four or more conferences. One interesting point is that the intersection of those two groups is relatively small (see the names in italics in table 1). Based on this result we added those authors and PC members which participated in three conferences. Figure 5 shows their distribution sorted by continents. This reveals a higher continuous engagement of North Americans in the Program Committees on the one hand, and more continuously active authors from Europe on the other hand.

No. of conf.	Authors		PC members
4	L. Dirckinck-Holmfeld D. C. Edelson G. Erkens G. Fischer M. Guzdial *U. Hoppe* G. Kanselaar V. Kaptelinin J. L. Kolodner F. Kusunoki	M. Lakkala T. O'Shea S. Puntambekar E. Scanlon R. B. Smith E. K. Sorensen M. Sugimoto H. Suzuki B. Wasson	Michael Baker Y. Engeström *K. Hakkarainen* E. Lehtinen H. Ogata
5	A. Fjuk L. Gomez *K. Hakkarainen* C. Hmelo-Silver L. Lipponen		C. O'Malley P. Dillenbourg R. Pea *U. Hoppe* *D. Suthers*
6	*T. Koschmann* G. Stahl *D. Suthers*		J. Roschelle
7			*T. Koschmann* N. Miyake

Table 1: Authors and PC members who participated in four or more conferences (intersection in italics)

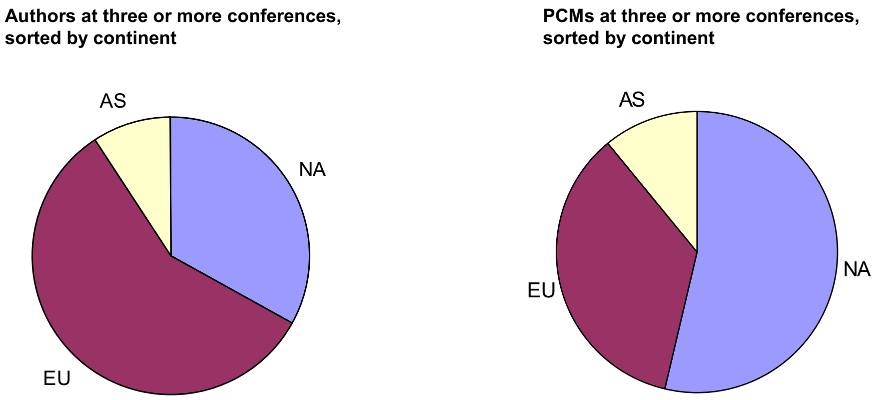


Figure 5: Authors and PC members at three or more conferences, by continents

Connections in the community

Connections in the community can be found by analyzing references and co-authorships. First we look at the references which we rate as a weaker connection than co-authorships. Figure 6 shows the references for the 1995 conference, figure 7 for the one in 2003. The figures include the references to all authors in the community in artifacts of the Top-88 authors (who contributed to at least three conferences). At a first glance it is seen that the number of nodes (=authors + referenced authors) increases from 1995 to 2003. This is not surprising because the number of authors increases and more CSCL related papers exist, e.g. in proceedings of previous conferences. But the interesting point in these figures is the growing number of international references. While in 1995 most references are national, in 2003 international subgroups arise. Concerning the large network in the middle of figure 7 it should be pointed out that national sub-groups (e.g. from France, Greece, Finland, Sweden, Canada, USA) grow together by referring to the same authors.

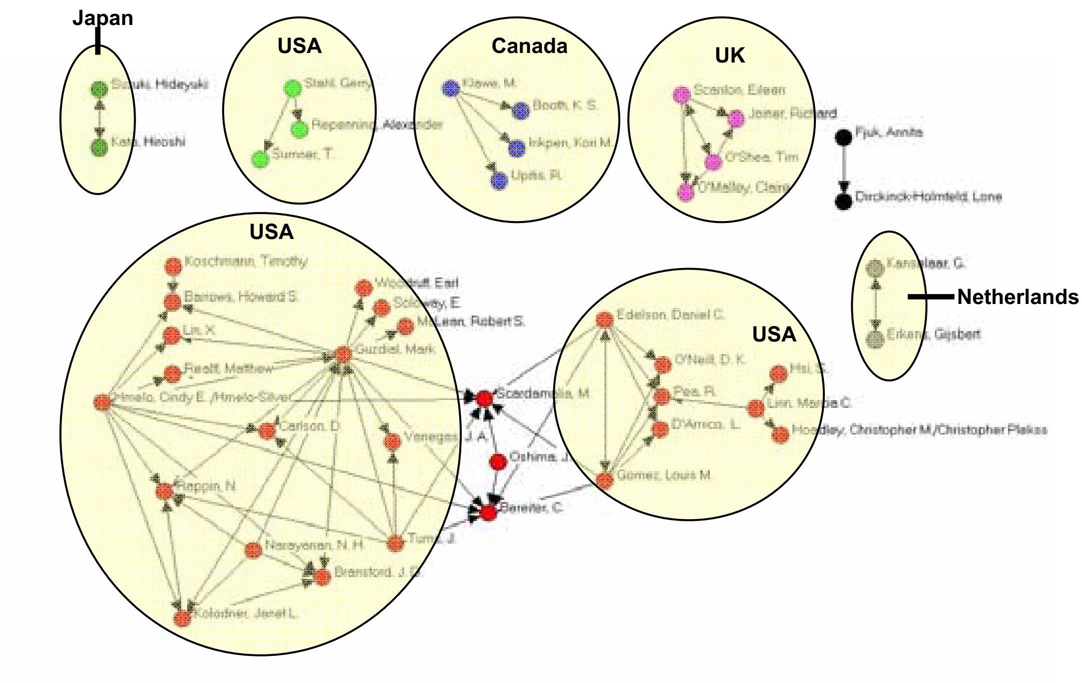


Figure 6: References in 1995

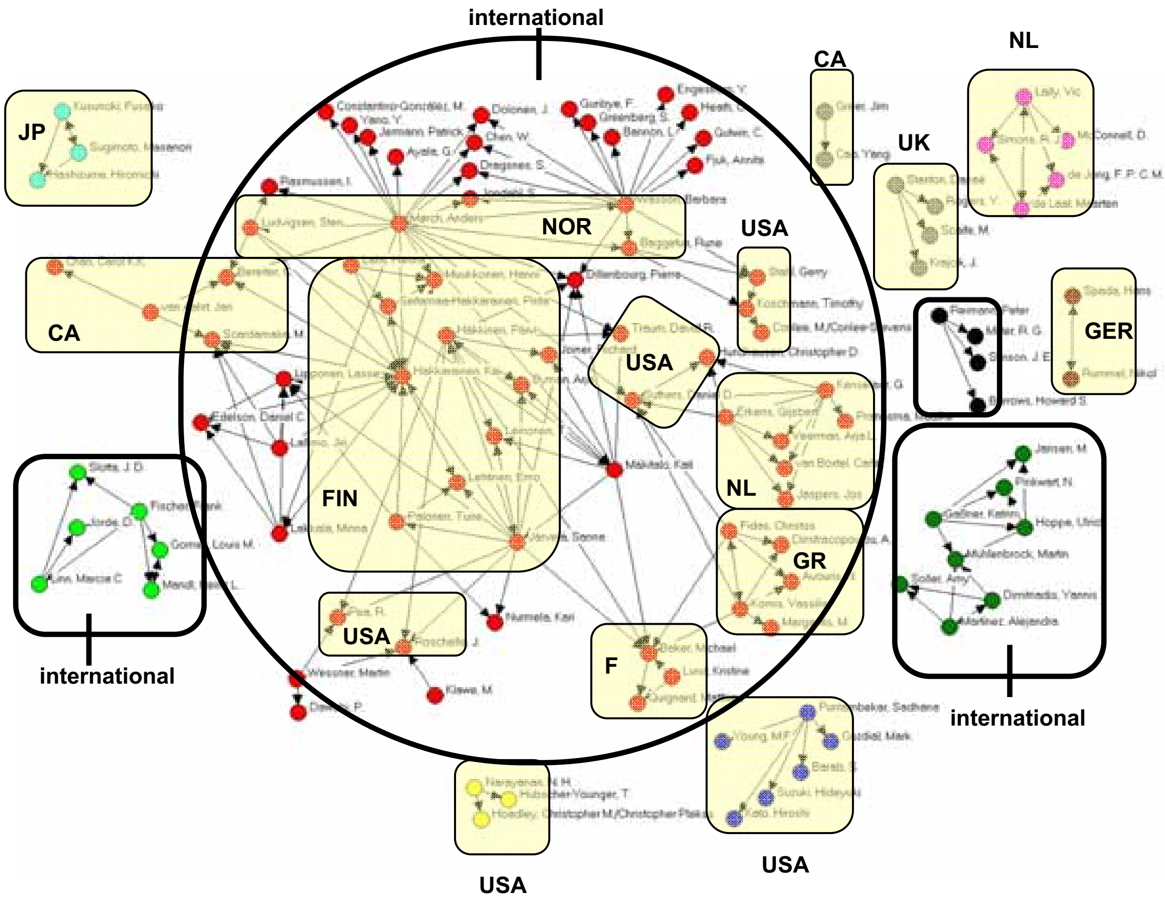


Figure 7: References in 2003

In a second step we try to verify this observation of growing international connection by analyzing the co-authorships which we rate as a stronger connection than references. Figure 8 compares the co-authorships of 1995 and 2003 on the abstraction level of countries concerning the papers (and co-authors) of the Top-88 authors. This data confirms the observation of growing international connection above. Here – as well as in the case of references – not only the number of nodes increases but also the international connectivity grows.

For 2003 we emphasize the close connection between authors from UK and Denmark (9+8 co-authorships) as well as from USA and Germany (8+8 co-authorships). A further interesting point is the large, national number of Finish co-authorships (61). This indicates a close meshed network with less connection to other countries though the view on the references (figure 6) suggests that finish authors are well positioned in the international (weaker) network of references.

To sum up, these findings support the assumption that the connectivity over regional boundaries grew over the last 10 years.

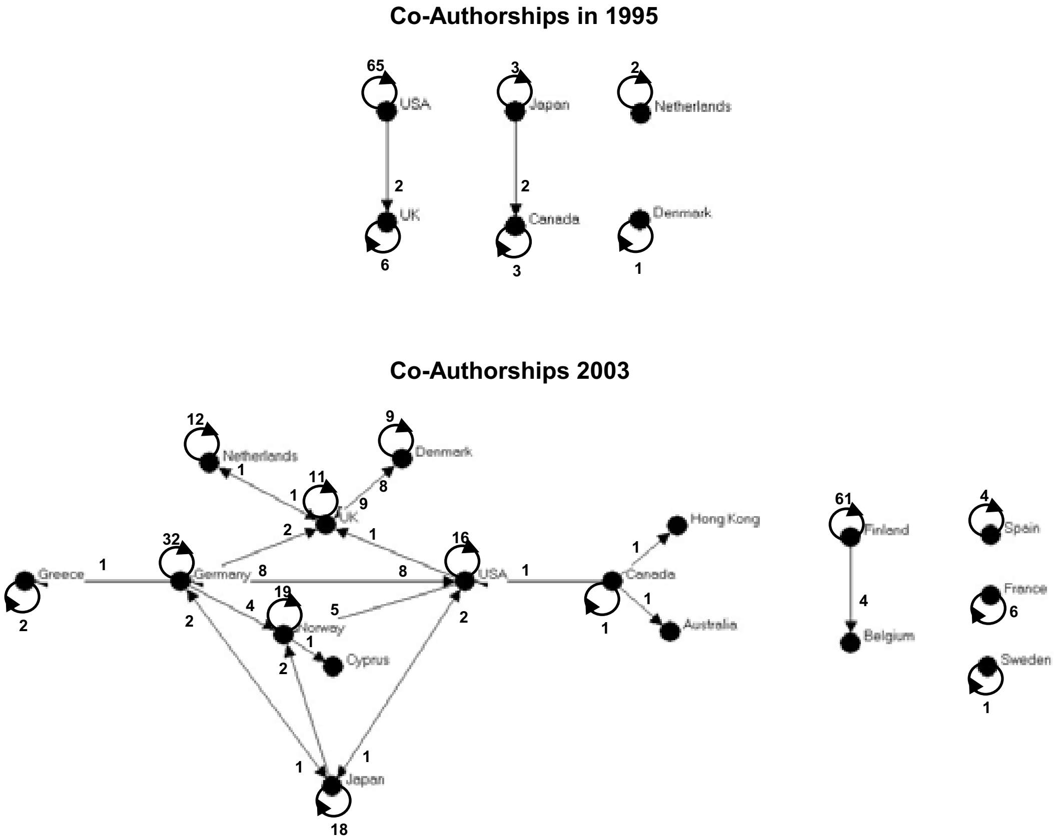


Figure 8: Co-authorships in 1995 and 2003

CONCLUSIONS & FUTURE WORK

In this paper we presented an analysis of the CSCL community concerning its development and continuity as well as the connectivity. This analysis is based on a mix of several approaches: we performed a citation and co-authorship analysis of CSCL conference proceedings and analyzed other sources including lists of participants and lists of program committee members. Most data confirm that the CSCL community is a lively and growing community with a small core group of recurring authors and PC members. In detail we showed that the group of authors (as active members of the community) grew and the group size of the PC members stabilized.

Furthermore the data revealed that the international distribution of the community members grows. This is caused by the rotation of meeting locations and the international composition of the PC members. The relation to the different meeting places is given because we were able to show that new people who live nearby the conference location entered the community and a substantial percentage of them also participated in a following conference. The relation to the group of PC members is derived from a comparison to a citation analysis concerning the International Conference of the Learning Sciences (ICLS) (Kirby et al., in press). It showed the same relation between PC members and internationality in a different direction: a program committee with members from one country only corresponds with a low degree of internationality in the group of authors. The community, especially the members in the core of the community should be aware of the data presented here as a basis for decisions about meeting locations, composition of program and other committees etc. In addition the data could provide help to predict future characteristics of the CSCL community, for example participation numbers for upcoming conferences. To sum up, for further development of the CSCL community we recommend that the internationality in the program committee as well as the rotation of meeting locations should be maintained.

The international connectivity of the community is also increasing which can be seen in a growing number of citations and co-authorships across different countries. In order to support the international connectivity in the community authors should take opportunities to work with people from other regions and share the results in (co-authored) papers.

A problem might be seen in the relatively high share of participants, authors, and PC members who participate in or contribute to only one conference. The data showed that the quotient between new and recurring authors and PC members started to stabilize - for PC members 33% are newcomers, for authors 66 %. The part of recurring authors seems to be quite low. As authors and their products play a very important role in the development of the community, this should be increased. In order to increase the probability that people come back to later conferences, the core group might think about measurements to increase the identification of members with the community. Pragmatically, members could be asked via email or during a CSCL conference to discuss issues related to the continuous participation in the community.

The work reported in this paper aims at providing a basis for an ongoing analysis of the CSCL community and for the design of its future. Possible extensions include:

- Updating the data for each new CSCL conferences in order to provide current data on its development to the community.
- Recording also references and co-authorships of authors with only one or two participations in order to learn more about the less active authors and how they are distributed and connected in the community.
- Splitting up the artefacts in posters, short and full papers for a more fine-grained analysis of development, continuity and connectivity of the community. (It could make sense to include also submissions which have been rejected, e.g. because of space limitations in the conference program.)
- Further specifying citations, e.g. in order to identify the publication types, series or even individual publications which are most influential to the community.
- Including information about disciplines of participants, authors and PC members in order to analyze the multi-/interdisciplinarity of the community.
- Performing a social network analysis in order to identify for example subgroups and cliques. Following more elaborated analysis methods (e.g., Chen & Carr, 1999), major research fronts and the evolution of ideas, research topics or methodologies in the community can be identified.

The approach taken here, a combination of citation and co-authorship analysis and the analysis of other sources such as lists of participants, authors and PC members should also be applicable to other scientific communities.

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Anonymity Options and Professional Participation in an Online Community of Practice

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Abstract. In this paper, we analyze a natural experiment regarding anonymity options and participation in a large, successful online community of practice (CoP) for U.S. soldiers. We study the impacts of changes of anonymity options on comment quality for productive discussion and professionalism. Four levels of personal attribution or anonymity of comments are significantly correlated with comment quality under some, but not all, circumstances. Eliminating anonymity options produced significantly fewer antisocial comments and fewer comments overall, although it did not affect overall peripheral participation as measured by logins and page views. Online identity or reputation appears to be more of a factor than external culpability in shaping user behaviors. Attitudes of participants and the evolution of norms over time are presented, and implications for the design of online learning communities are discussed.

Keywords: Community of practice, anonymity, norms, flaming, facilitation, moderation, participation, online discussion, asynchronous discussion

INTRODUCTION

The development of the theory of communities of practice (Lave & Wenger, 1991; Orr, 1990; Wenger, 1998) has led to numerous attempts to create, support, and shape online communities of practice for social learning. Communities of practice are networks of practitioners who interact socially to become more effective in their practice individually and collectively. Through such networks, novices are initiated into the practices of the group, norms for the practice are negotiated and communicated, and increasing expertise in and identification with the practice is accompanied by more centrality in the community. The model is linked to Vygotskian notions of social appropriation of knowledge (Newman, Griffin, & Cole; Wertsch, 1985).

Although many communities of practice do occur naturally without external intervention or initiation, their deliberate facilitation as a means to learning, especially in professional contexts, has been widely proposed and sought. Oftentimes, such approaches rely on the use of technology to support or sustain the community, especially in fields where the practitioners may be isolated from each other, for instance among teachers (Schlager, Fusco, & Schank, 2003; Barab & Duffy, 2000), engineers and international development experts {Wenger, McDermott, & Snyder, 2002}, U.S Army officers (Dixon, Allen, Burgess, Kilner, & Schweitzer, 2005), Canadian educational coordinators (Gray, 2004), and globally distributed scholars (Scardamalia, 2003).

Communities of practice differ from some other forms of online learning in that they are primarily centered on learning via apprenticeship or legitimate peripheral participation, and thus there is no "teacher." Any member of the community sufficiently central to the practices of the community can support the learning of other, less enculturated members, and even the questions and errant comments of novices can spark learning across the community. The relevant knowledge is presumed to reside in and among the minds of the practitioners themselves (Dixon, et al.; Wenger, 1998), and CoPs are valuable to the extent that they draw out, share, and generate that knowledge.

What, then, drives individuals to learn in a CoP? Identity is an important component of learning in a community of practice. Indeed, identity can be viewed as the driving factor that connects individual cognitive experiences to joining, or repulsing, a community of practice, and hence, learning (Nasir, 2002). Individuals perform their expertise to legitimize and more fully realize their membership in the community.

Technology plays a powerful mediating role in how identity is developed and expressed (Turkle, 1995), and thus provides a lever for changing what kinds of behaviors and norms develop within online or blended communities. Technology provides new opportunities for attribution and anonymity, and may permit the construction of alternative identities in a learning context (Chester & Gwynne, 1998). This fluidity may create a safe space for individuals to explore identity development, which is an important component of development and learning (Halverson, 2004), but it also has implications for social norms and standards. In particular, personal responsibility for one's actions and social norms such as reciprocity, honesty, trust, and so forth may be damaged in environments where identity is too fluid (Chester & Gwynne, 1998; Herring, 1996).

Research on the impact of anonymity on participation in an online learning community is inconclusive. Chan, Bandar, Oh, & Chan (2004) found that the use of actual identities in an online community increased participation, a position supported by Millen and Patterson (2003). In contrast, Chester and Gwynne (1998) found that anonymity increased participation, especially among minority students. In Hsi and Hoadley (1997), anonymity was not found to significantly affect the amount or quality of participation, although it did alter the students' perceptions of social safety. But later work found that the *possibility* of anonymity could contribute to perceptions of social safety, without actually being commonly used. Moreover, anonymity can erode effective participation in online learning conversations; later work in the same context found that learners were less likely to read comments that were posted anonymously (Hoadley, 2002, 2004). Because this is hypothesized to challenge the conditions of a productive discussion (Hoadley, 1999; Hsi, 1997), anonymity can be of mixed value in fostering learning in an online community.

A significant challenge to understanding the interplay of anonymity, identity, participation, and learning in an online community of practice is the many varieties of CoPs (educational, professional, distributed, blended, etc.). Comparisons of the effects of relative anonymity are difficult to make when the CoPs being compared are themselves different. In our review of the literature, we did not find any study like this one, which examines how a change in anonymity options affected a single, robust online community.

METHODS

In the following sections, we explore the results of a natural experiment with anonymity options in an online community of practice for peer learning among soldiers in the U.S. Army. First, we describe the online community as a context for professional learning. Next, we describe how circumstances led to policy changes on anonymity. These policy changes created a natural experiment for different kinds of identity options ranging from full anonymity to linkage with a user's online identity to linkage with the user's offline identity. Finally, we examine the impacts of these shifting options on participation and learning-oriented behaviors in the online community, and discuss the relationship between identity and communities for learning.

The PlatoonLeader community

PlatoonLeader is an online community of practice of platoon leaders in the U.S. Army. Platoon leaders are responsible for groups that typically include 20-40 people, and being a platoon leader is usually a newly commissioned officer's first job in the Army after completing initial training. The Web site brings together past, present, and future platoon leaders in an open exchange of leadership experiences, tools, and ideas related to becoming more effective leaders. The purpose and values of PlatoonLeader are stated across the top of its homepage:

> PlatoonLeader is the professional forum for United States Army platoon leaders--current, past, and future. We support each other's efforts to become more effective platoon leaders.
>
> Professionalism is our watchword. We speak candidly, but always with respect to each other and loyalty to our commission. We tackle our leadership challenges with a positive voice, focused solely on building and leading combat-ready teams.

PlatoonLeader was launched in 2001 as a private, non-profit effort by Army officers who recognized that their own professional learning developed primarily through experience and through conversations with their peers, rather than formal training. They sought to connect current platoon leaders with each other for mutual support and learning, and to connect experienced platoon leaders with novice ones to promote the sharing of experiential knowledge. The community was successful, and in 2002 the Army began to fund its operations. As of this writing in November 2004, PlatoonLeader has over 16,000 registered members and is growing consistently at a rate of 25 new members per day. In the 30 days prior to this writing, the site averaged more than 700 unique visits, 9000 page views, and 50 new discussion comments per day. Membership and participation in PlatoonLeader is entirely voluntary.

In its initial two years of operation, PlatoonLeader was open to the public and did not require participants to login. Participants could post anonymously. By August 2003, however, the moderators of the community were frustrated by frequent "flame" comments that threatened to give the community a negative tone. Online behavior was becoming inconsistent with the community's stated purpose and values. Several community members told the moderators that they no longer participated because of the unprofessional behavior of some participants, almost all of whom posted anonymously. In an attempt to promote productive professional conversation by discouraging anti-social comments, on September 15, 2003 the moderators changed the rules of the site to forbid anonymous postings. Members had to login to post, and their usernames appeared with their comments. This change led to an immediate and noticeable decrease in anti-social comments. In the spring of 2004, in response to concerns about information security in a time of war, the moderators of the site restricted access to PlatoonLeader to members of the U.S. military. Beginning in March 2004, all new members had to register using their military email address (linked to their real name), and in April 2004 all existing members were told to update their accounts with their military email addresses. In May 2004 all accounts not linked to a military email address were purged. Because military email addresses include the soldiers' real names and official contact information, by June 2004 participants in PlatoonLeader were aware that the moderators of the site (although not the site's other members) had access to their real identities. The purpose of this study was to determine if the tone of the conversation had indeed improved, and, if so, the likelihood that the improvement was due only to chance.

Data sources and coding

In the section that follows, we describe our participation data from the PlatoonLeader community under the three different anonymity conditions. The primary data came from the comments produced during three sample months: August 2003 (when anonymous posts were still permitted), October 2003 (immediately after the requirement that participants had to be logged in to post a comment), and June 2004 (immediately after all accounts that didn't link to the member's real identity were purged). Comments from every third discussion thread were collected and analyzed (threads 1, 4, 7, and so on). Only comments produced during the months of analysis were considered (many threads have comments spanning several months.)

Table 1: Conditions Determined by Months and the Policy Rules in Place

Sample	Month	Policy-Determined Minimal Level of Attribution
Condition 1	August 2003	Anonymous comments permitted (Guests can post messages without logging in at all)
Condition 2	October 2003	Comments required to have handles/usernames (Users must register with a valid email address, and must be logged in to post, but profile information is not validated; all comments are linked to username)
Condition 3	June 2004	Comments required to have usernames linked to actual identities (Users must register with email addresses provided by the military which are linked to real identity; all comments are linked to username, and administrators can uncover real names)

In addition, users participated in an online poll (survey) linked off the opening page of the website which was available for nine days in April 2004. User comments from this survey (and in some cases, follow-up email comments) shed light on participant attitudes towards the site. These polls were, however, a self-selected sample of the users of the website; members were not forced to respond to the poll in order to participate in the online community. Finally, site logs were used to help determine overall rates of participation on the site.

Coding rubrics: Anonymity and comment quality

Each of the comments in the sample was coded on two dimensions: attribution or anonymity, and comment quality (with respect to professionalism and productive discussion).

Comments were coded for one of four levels of anonymity. Level-1 (anonymous) comments were made by guests who weren't logged in to the system and were thus completely anonymous. Level-2 (pseudonymous) comments required user login and were linked to a username, but weren't linked to a user's real name or identity. Level-3 comments were attributed to an individual because the member had chosen a username that indicates his or her real name (e.g., johndoe). Level-4 attribution occurred when a user explicitly highlighted their real name in the body of the post itself by signing it or including their signature block. The system permitted such a signature to be configured as a default for each comment, but users could easily turn this feature on or off for each post.

Table 2: Coding Rubric for Anonymity of Discussion Comments

Level of Anonymity	Description	Example identifier
Level 1	Anonymous	Anonymous
Level 2	Username only	Rogue6
Level 3	Username that indicates real name	Timsmith
Level 4	Signed with real name	s/Timothy Smith, 123rd Armor Bn

Comments were also coded for quality, a construct that captured what effect they would be expected to have on professional conversation and other members' willingness to participate constructively. Level-1 comments were very negative posts that included vulgarity as they demeaned another member, were obvious "flame bait," or were cynical toward the profession. An example Level-1 comment is, "Yeah, it's called CTLT, dumbass. I hate to say it, but that 'don't need to eat shit' nut job was right. Now shut up and go back to ROTC." Level-2 comments were negative posts that criticized another participant (criticism of ideas was acceptable) or were cynical toward the profession but did not include vulgarity. An example Level-2 comment is, "Please tell me you're joking when you say you can't remember if live rounds are crimped or not. No one can be that dumb. One round is missing the projectile, one isn't." Level-3 comments were positive posts that asked a relevant question, answered a question, encouraged or validated a previous poster, chatted in a friendly way, redirected a discussion positively, expressed thanks to another member, or added humor to the discussion. A typical Level-3 comment was, "I think it's division policy here that no one can wear contacts. You set yourself up for problems with all the sand getting in your eyes. You have a greater risk of infections, etc. Maybe check with the eye doctor on post for their take or the official policy." Comments deemed neutral in their effect were coded as Level-3, on the assumption that any participation that isn't negative at least involved a member and is thus a positive act. Level-4 comments were very positive posts that included two or more of the criteria for a positive post, were exceptionally long with quality information, or included specific information (e.g., a link to a specific part of a regulation) that indicated a commitment of time and effort to help another member. A Level-4 comment that immediately followed the example Level-3 comment was, "You can get LASIK and PRK done by the Army depending on where you are stationed. Be aware that after surgery you are non-deployable during healing (~6 months). You can find more info at… [URL to information resource]"

Table 3: Coding Rubric for Comment Quality

Quality of Comment	**Description**	**Example**
Level 1	Very negative: demeans with vulgarity	Get lost you dumbsh*t!
Level 2	Negative: critical of another, or cynical	You're as screwed up as the Army.
Level 3	Positive: supportive of another or Army	The way I did it was…
Level 4	Very positive: include multiple positive criteria	Here's the url you need…good luck!

Research ethics

Institutional Review Board (IRB) approval was obtained for this study. Informed consent was obtained from those who completed the survey. The discussion comments were treated as publicly available data. Under conditions 1 and 2, they were directly available to the worldwide public. In condition 3, they were available to over one million U.S. Department of Defense personnel. All data was aggregated, and no effort was or will be made to link it to anyone's identity.

Intercoder reliability

A volunteer not related to the study but who is a member of the PlatoonLeader community independently evaluated 100 of the comments based on the quality rubric to determine intercoder reliability. This second coder had 93% concurrence in terms of whether comments were positive or negative, and 84% agreement on the intensity of the comments (i.e., exact coding match).

RESULTS

Below, we discuss the results of three distinct analyses. First, we describe patterns of anonymity and participation in each of the three conditions. Then, we discuss the relationship between anonymity and comment quality (productiveness or professionalism). Finally, we discuss the results of the user poll and provide some participants' beliefs on anonymity in the community.

Patterns of anonymity and participation by condition

In the first condition, where users were permitted free choice of whether to comment anonymously or not, nearly half of all posters did so anonymously. In our sample, 348 of 707 comments were made anonymously (Level 1) in August 2003 (Condition 1). This may have been due to an explicit desire to remain anonymous, or due to the ease of commenting without bothering to log in to the system.

Figure 1: Attribution by condition

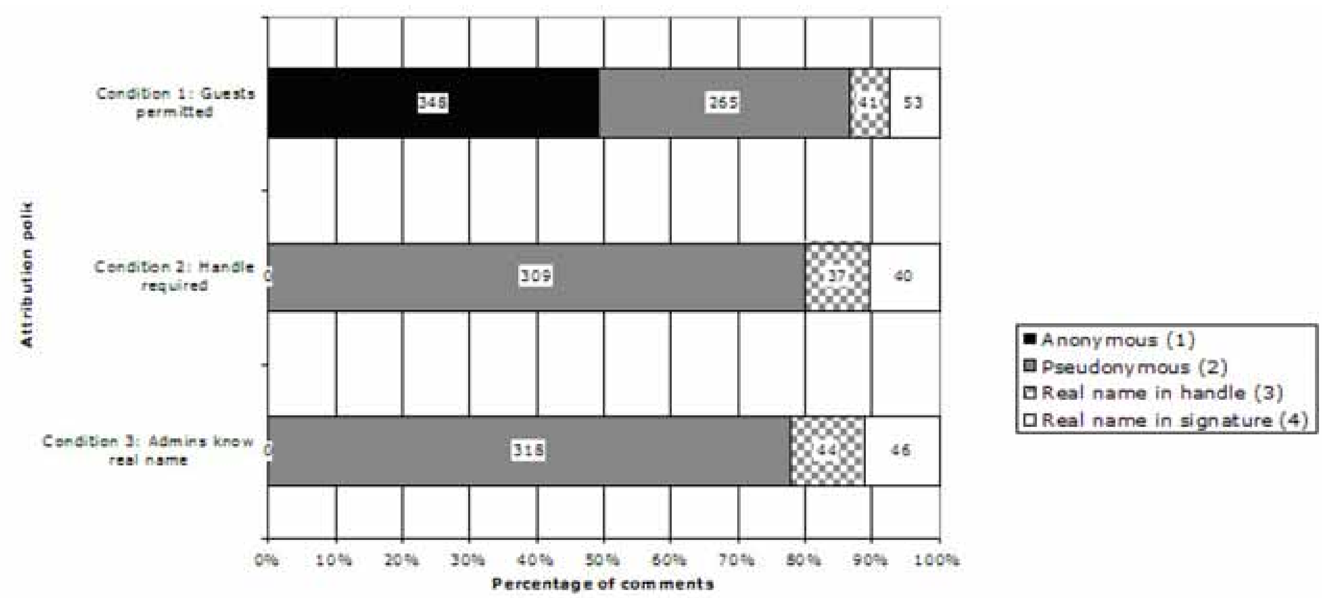

Figure 1 shows the patterns of anonymity in each condition. In Conditions 2 and 3, most users still preferred to stick to Anonymity Level 2, in which their words were identified by only a handle or username, and this username did not reflect their real name. This would be the default choice provided by the system, assuming the user had not selected a username that contained their real name. Even so, the percentages of comments linked to identities did go up over time (13% in Condition 1, 20% in Condition 2, 22% in Condition 3).

Elimination of the option to post anonymously appears to have led to a substantial decrease in overall comments posted in the community and to a moderate increase in peripheral participation. 2,148 comments were posted under Condition 1 in August 2003. Under Condition 2 in October, only 1,283 comments were posted, a 40% decrease. Yet, measures of peripheral participation increased. Between August and October, unique visits to the site and page views increased approximately 10%. Unfortunately, a server crash resulted in the loss of participation data from January-July 2004, so we cannot report participation data for Condition 3.

Table 4: Condition and Participation

Anonymity Rules and Month	Unique Visits/ Page Views	Posts Contributed
Condition 1: Augusts 2003	46,040 / 339,067	2,148
Condition 2: October 2003	51,374 / 371,029	1,283
Condition 3: June 2004	N/A	N/A

Anonymity and comment quality

Comments in the system were generally positive and helpful, with a mean of 3.1 (n=1501, sd=0.47). In particular, only 90 (6%) of the 1501 comments were "flames" (coded as negative or very negative), and only three earned the worst rating. 248 comments (17%) were coded at the highest quality level.

Overall, there is a strong relationship between anonymity and our measure of quality (professionalism and productive discussion). Anonymity as measured on our four-point scale correlated significantly with the quality measure r=.217, N=1501, p<.0001. Of the 90 negative comments (Quality Levels 1 and 2), 84 (93%) were made with some level of anonymity (Anonymity Level 1 or 2), and only six were linked to the participant's real name (Anonymity Level 3 or 4). On the other hand, 73 (29%) of the 248 most positive comments (Quality Level 4), were linked to the participant's real name, and 40 (16%) were explicitly signed by the contributor (Anonymity Level 4). Clearly, people prefer to make negative comments anonymously.

Quality by condition

How did the change in anonymity policies affect the professionalism or productiveness of the comments? Elimination of the option to post anonymously achieved the moderators' desired effect: flaming decreased sharply, from 11% to 2% of all comments. An ANOVA on condition revealed a significant main effect F(2, 1498)=19.48, p<.0001. Using Fisher's PLSD, Condition 1 was significantly different than each of Conditions 2 and 3, but these last two conditions were not significantly different from each other. See Tables 4 and Table 5.

Table 5: Comment Quality by Condition

	1-Very Negative	2-Negative	3-Positive	4-Very Positive	Mean
Condition 1 (n=707)	0% (2)	11% (77)	75% (530)	14% (98)	3.02
Condition 2 (n=386)	0% (0)	2% (7)	79% (306)	19% (73)	3.17
Condition 3 (n=408)	0% (1)	1% (3)	80% (327)	19% (77)	3.17

Table 6: Effects of condition on quality

Fisher's PLSD for comment quality

	Mean Diff.	Crit. Diff.	P-value
Condition 1, Condition 2	-.147	.058	<.0001*
Condition 1, Condition 3	-.152	.057	<.0001*
Condition 2, Condition 3	-.005	.065	.8678

The relationship between quality and anonymity varied across the three conditions. The correlations between quality and anonymity in Conditions 1 and 3 were significant and positive (r=.215, N=707, p<.0001; r=.166, N=408, p=.0007) while the correlation in Condition 2 was positive but insignificant (r=.057, N=386, p=.2650).

Participant reactions: In their own words

In April 2004, after the option to post anonymously had been removed but before most accounts were linked to personal identifiers available to the administrators, we polled members on their preferred level of anonymity for the community and offered them the chance to explain their vote. Sixty-three members participated in the voluntary poll, and forty-six of them added comments. Although 17% of respondents preferred total anonymity, twice that percentage (36%) preferred options that attributed the contributor's real name to each comment. Almost one-half of the respondents, however, indicated a preference for a middle-ground position in which posts were attributed to the contributor's username. The preferred level of anonymity, then, was the one used most often by users under all contributions during the course of this study—comments attributed only to the contributor's username.

Table 7: Member Preferences on Anonymity Policy

Anonymity Policy	Respondents Preferring
Total anonymity permitted in posts	17.2%
Username only	45.3%
Username with real name available in profile	18.8%
Actual name required in posts	17.2%

The reasons respondents offered reflected a tension between the dual community goods of candor and responsibility. Those who thought that anonymous comments should be permitted appealed overwhelmingly to the perceived need to speak candidly without being constrained by a fear of retribution. "The forum should be a place where leaders can vent and express opinions without fear of repercussions," said one respondent. Another member commented, "I'd be reluctant to say what I truly feel, especially if it's unpopular, if I thought it may come back to haunt me. You never know who you can [anger] out there or whose command you wind up in later on down the road."

At the other end of the spectrum, respondents who thought that all posts should include the member's real name justified their position in terms of promoting responsible online behavior and credibility of information. One member put it this way:

> I object to anonymous posting for several reasons. The first is a matter of trust. This is a professional forum; if you place enough value in your opinion to have posted it for everyone to read, you should be brave enough to attach your name. Anonymous messages have -zero- credibility: if you don't have the integrity to attach your name to your opinion, why should I take the time out of a busy day to read it? Secondly, I have seen the effects of anonymous posting back when it was allowed on platoonleader. This led to thousands upon thousands of stupid, time- and resource-wasting 'joke' messages. I come to the site to discuss serious things with serious people, not read ten thousand anonymous messages about [stupid topics]. There are supposedly benefits to having anonymous postings. I have heard the 'worrying about repercussions' argument, among others, but it just doesn't seem to hold water. The benefits, if any, are minuscule; the problems anonymous posting creates are enormous and wasteful. Please don't bring it back.

Nearly half of the respondents supported the option for pseudonymity in their community. Their comments emphasized that this option facilitated candor while reigning in the excesses of total anonymity. As one member put it:

> While I think that the anonymous posters, as a group, detracted from the professionalism of the site, I still think a limited amount of anonymity is a good idea. It fosters a more heated debate forum where real opinions, rather than the "party line" can be expressed. Anything dangerous or truly unprofessional can be pursued by a moderator of the forum through the user's army.mil address, but for the most part, this site should still remain a vaguely anonymous arena for honest and candid discussion.

Interestingly, the arguments for anonymity generally argued from the point of view of the poster, while the arguments for attribution argued from the point of view of the reader. We return to this issue later.

DISCUSSION

To sum up, attribution or anonymity policies can have a significant effect on the professionalism and productiveness of comments posted in an online community of practice. Eliminating the option to post anonymously nearly eliminated negative comments, reducing their occurrence by 89% during a period in which member visits and page views increased approximately 10%. By increasing attribution within the community dialogue, a higher percentage of productive comments were read by more members more often.

Interestingly, pseudonymity is compatible with responsible online behavior. There was no statistically significant change in comment quality when actual identities were linked to usernames. This helps shed an important light on why attribution matters. In Condition 2, users had the option to participate online using a "throwaway" email account, such as a hotmail or yahoo email address. Thus, it is unlikely that there would be any real-world negative repercussions to inappropriate behavior. And, given that the vast majority of comments posted were at Anonymity Level 2, users were unlikely to obtain real-world recognition for their positive behavior. Why then did behavior change radically between Conditions 1 and 2, but not between Conditions 2 and 3? Online social reputation may be more significant than concern for adverse repercussions in shaping participant behavior. In other words, these results suggest that building and maintaining an identity within the community of practice may be more important than real-world professional rewards or sanctions such as raises or disciplinary actions.

Two incidents that occurred outside the direct scope of this study corroborate this interpretation. In the course of this research, we discovered one section of the site that the moderators had overlooked when they turned off the option to post anonymously and thus allowed users to violate the standard site policies about attribution. That section had 13 posts, 4 of which were posted anonymously. Of those 4 posts, 1 would have been coded as negative in quality. So, 1 of the 13 comments, or 7%, were negative, which is well above the rate for the rest of the site during that time period. This anecdote, while statistically insignificant, is nevertheless consistent with our finding that many members will post anonymously if given the option, and will be more likely to make negative comments if they post anonymously.

A second incident reveals the importance of online reputation in a pseudonymous environment. In October 2004, an active member (179 posts) uncharacteristically posted a very negative comment about another member. Immediately, other members of the community pointed out the inappropriateness of the comment, and the poster edited it. The target of the libel, however, contacted the moderators of the site to request the poster's identity to pursue legal charges. When the moderators contacted the wayward poster about the issue, the member had a two-fold response. On the one hand, he took responsibility for his actions, expressed his willingness to face legal punishment, and contacted the person he had libeled and apologized. On the other hand, he asked that his username be changed, saying, "People will hold it against me. I need a fresh start." Remarkably, he seemed more concerned about his status in the community than he was about facing possible legal proceedings.

The latter story provides insight into a strength of the PlatoonLeader community—the high level of trust between the moderators and the members. The strong support for pseudonymity in the member survey was augmented by statements of confidence in the moderators' role in addressing bad behavior. Absent this confidence that the moderators would protect them from flamers and protect their identities, members might be more inclined either to demand more attribution (to deter flames) or to want more anonymity (to protect their own ability to speak candidly). This moderation may be the key to negotiating the differing goals of the posters and the readers that were evident in the poll.

A natural constraint that increases the validity of this natural experiment is that the moderators did not have the option to delete member accounts; doing so would have caused any threads the members participated in to crash. The improved member conduct in Conditions 2 and 3, then, is apparently not due to "culling the herd" of troublesome members.

In this study, we measured "comment quality" in terms of its professionalism and impact on productive discussion, but we did not attempt to judge its quality directly in terms of learning value. Coming from the perspective of social learning theory (Wenger, 1998), we believe that learning occurs through participation in a community of practice. Through members' legitimate peripheral participation in a community, they come increasingly to adopt the community's practices, identify with it, and find meaning in it. In this study, we see that increased levels of online identification (through the elimination of online anonymity) led to a higher ratio of professional interaction among members and increased peripheral participation by members. Those are indications of increased learning value in the community.

An interesting question for further research is the role that a community's maturation has on whether anonymity levels affect productive behavior and learning. The relatively short duration of this study in a community that was already two-years old would seem to limit the impact of maturation as a conflating variable. Still, it's unknown how the community would have reacted to the elimination of anonymity if it had been less mature. There is need for further study to gain a better understanding of the relationships between online anonymity, online behavior, identity formation, community maturity, and learning in an online community of practice.

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The Evolution of the Intellectual Partnership with a Cognitive Tool in Inquiry-Based Astronomy Laboratory

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Abstract. This paper describes a study focused on the longitudinal application of a cognitive tool by observing a pair of learners' interaction with it over a semester. This study intended to develop a deeper understanding of the process whereby learners become more capable of engaging in scientific inquiry with the tool in order to advance technology-enhanced, inquiry-based approaches to instruction. In an effort to understand how learners move toward coherent knowledge structure, eccentricity of planet's orbit emerged as one of the main themes. The findings are discussed focused on how the pair used, understood, and elaborated the concept of eccentricity.

Keywords: Distributed cognition, expertise, cognitive tool, inquiry-based learning, modeling

Inquiry-based pedagogies focus on the question of how people solve problems and create explanations about the world (Greeno, Collins, & Resnick, 1996). Advances in technology have introduced computerized modeling and visualizations to scientific inquiry practices, which can be considered as cognitive tools of scientists. Hoping for the result of better instruction, recent research examines how the inclusion of technology in inquiry-based learning supports people's inquiry processes. Adopting these tools for educational use has a lot of advantages in engaging students in cognitive activities that are similar to those of scientists.

The failures of adopting this approach come from our assumption that learners will automatically have rich experiences as novice scientists (Pea, 1993; Perkins, 1993). The intervention of modern inquiry tools does not guarantee learners' engagement in modern scientific inquiry. It often gives learners multiple challenges of understanding the tools and inquiry processes in addition to the scientific contents. However, there are not sufficient investigations regarding how learners come to use tools in profound ways, how learners' growing expertise in use of tools for scientific inquiry impacts their development of intellectual partnership with it, and how this partnership evolves over time. As a result of the partnership, the ways in which students construct their understandings with their tools should become consistent with scientists' practices. Therefore, questions about learners' development of cognitive partnerships should be explored to adopt these approaches in the classroom.

The purpose of this study was to develop a deeper understanding of the process whereby learners become more capable of engaging in scientific inquiry with a computer tool over time. A second goal was to learn how to improve technology-enhanced, inquiry-based approaches to instruction. We assumed that modeling-based inquiry and the use of the Astronomicon program would result in students' acquiring practices that resemble those of scientists. With the theoretical belief that a certain activity, like an inquiry, task forms a particular kind of a learner-tool joint system, the overarching research question was this: Over an entire semester how do groups gain expertise in the use of the tool for scientific inquiry and develop intellectual partnership with it?

CONCEPTUAL FRAMEWORK: COGNITIVE TOOLS FOR SCIENTIFIC THINKING

Cognitive tools can be defined simply as aides for cognitive tasks such as complex calculations (Lajoie, 1993) or more sophisticatedly as "technologies that enhance the cognitive powers of humans during thinking, problem solving, and learning" (Jonassen & Reeves, 1996). The theoretical foundation of cognitive tools comes from the theory of distributed cognition, which regards cognition as residing not only in a person's head, but distributed among people, artifacts, and symbols (Salomon, 1993b). A computer becomes a cognitive tool when it performs cognitive tasks together with learners. Computer is no longer perceived as a mere delivery medium, but as a tool with unique capabilities that complement learners' cognition (Kozma, 1991). As computers have been described as "partners in cognition" (Salomon, Perkins, & Globerson, 1991), we regard learners and cognitive tools as intellectual partners that have reciprocal interactions during learning activities. The conceptual framework of this research started with the ideas of distributed cognition and was elaborated with the *theory of expertise.*

Expertise is diversely defined as a standard of expert performance (Ericsson & Smith, 1991), as a relative degree of excellence for an activity (Salthouse, 1991), and as some degree of proficiency in our everyday activities (Carlson, 1997). Experts rely on the environment and technology, and capabilities of using them are part of their expertise (Stein, 1997). Within the field of instructional technology, however, expertise has been discussed and employed mostly in such areas as intelligent tutoring systems and expert systems. These systems model and perform the experts' cognitive processes. In contrast to the approach to represent the expert processes, we should focus more on the roles of technology in experts' practices.

The expertise view of technology adds specificity to the distributed notion in that the technology becomes one of the most important assets of the involved activities. With these two theories together, the interactions among learners and tool within an activity represent the expertise of the distributed cognitive system. In other words, cognitive tools can be regarded as having some kind of expertise, forming a joint system of learning.

Joint Learning System for Scientific Inquiry

Cognitive tools for scientific inquiry are developed by emulating or modifying scientists' tools. These tools complement the scientific investigation process during the learners' inquiry as if experts use computers for their professional activities. The main purpose of a cognitive tool varies from organizing and representing learners' thinking to creating actual products (Ericsson & Smith, 1991; Perkins, 1993). Activities using cognitive tools should promote the ways in which tools are used in the world because the capabilities of a tool become worthwhile only because of the activities the tool affords (Salomon, 1993b).

How a joint learning system works in concert with scientific inquiry should then be given significant emphasis for our research and development. The Learning Through Collaborative Visualization (CoVis) project, for example, has gone through the iterations of research and development in order to promote open-ended inquiry within constructivist learning environment (Edelson, Pea, & Gomez., 1996). The major component of the CoVis project is its investigation tools for learners, such as World Watcher. World Watcher allows users to select units, examine visualizations at varying scopes, customize the display of visualizations, and analyze and create data with mathematical operations or other metaphors (Edelson et al., 1999). This opens up a novel opportunity for learners to dynamically observe different parts of the world, which is impossible to do without such tools. In their global warming curriculum, students prepared briefings of their investigations for a fictitious international conference, providing authentic experiences as novice scientists (Edelson et al., 1999).

Development of the Joint Learning System

The cognitive growth of an individual cannot be understood without understanding the development of joint relationships, because a person's growth is indeed the result of the distributed work with the environment (Karasavvidis, 2002; Salomon, 1993b). The outcomes of cognitive tasks include not only constructed knowledge or performance, but also resulting cognitive process and distributed structure, which are important parts of the cognitive development (Salomon, 1993). When the participants of distributed cognition continually work together, this particular distributed system is likely to develop into a stronger one. Individuals discover more affordances of the tool and even bring out more abilities of themselves as they develop the distributed relationships. Therefore, the tool and learners better contribute to the performance (Pea, 1993).

This idea of joint learning system development becomes much more perceptible by applying the concepts from the theory of expertise. The elements characterizing performance of experts can be summarized as *knowledge*, *functions*, and *representations*. Experts process their knowledge during performance from more deductive ones (e.g., rules and formulas) to more inductive ones (e.g., information about exemplars) (Patel & Groen, 1991). They use cognitive functions varying from simple information search and rule execution to higher-ordering thinking and problem solving (Ericsson & Charness, 1994; Perkins, 1993). Experts generate complex representations about problems they encounter, which provide images to support constant reflections on and improvements in their decision making and actions (Ericsson, 1996; Glaser, 1996; Winn & Snyder, 1996). These three elements work together with significant roles in expert performance and development. In developing expertise, especially in early stages, one should develop a basic structure of expertise in the domain, which involves better use of a learner's cognitive functions, gained knowledge structure and external representations, and some automaticity in the performance processes (Keating, 1990; Schneider, 1993; Winn & Snyder, 1996).

Knowledge

In structuring knowledge, novices first make cognitive efforts to understand the nature of tasks in the domain and to find important information and then to organize their knowledge into more accessible structures (internal representation of knowledge) (Schneider, 1993). To develop expertise, learners constantly face problems that challenge the current level of knowledge and competences, requiring them to reorganize the existing fragmented knowledge and connect with new concepts. Cognitive functions are better facilitated for use when knowledge is organized in a coherent way (Glaser, 1996). As a joint learning system, learners' knowledge, the tool, and the current setting (activity and environment) are organized and accessed at the time of performance. This organization changes each time they come together as their activity changes and their knowledge develops.

Functions

The learners' growing expertise in the domain and increasing familiarity with the tool are important to perform better in inquiry activities. The partnership of the joint system remains weak for some time, and then learners gradually make more effective use of the tool, developing into a stronger joint system (Pea, 1993). Suggested by scholars in distributed cognition, higher-order thinking such as problem-solving and pattern recognition and executive functions such as deciding what to do and where to go are the main roles of the learners to perform tasks (Perkins, 1993). The technology processes rules, such as producing representations with inputs and retrieving information, but cannot understand the meanings of representations and activities (Salomon, 1993b).

Novices approach problems with strategies that are based more on concrete information, and then they use more abstract reasoning as they gain expertise (Anzai, 1991; Patel & Groen, 1991). Novices rely on the surface features of the problem, commonsense knowledge, and trial-error approaches due to the lack of their domain-specific knowledge base. They start using a weak method, which uses observation and problem reduction, instead of starting with underlying principles. Experts approach problems with a strong method, using a working hypothesis and relying on the systematic representation and their domain-specific knowledge (Anzai, 1991; Patel

& Groen, 1991). Experts focus selectively on relevant information and switch between weak and strong methods depending on the problem (Anzai, 1991; Patel & Groen, 1991; Scardamalia & Bereiter, 1991). The processes of giving selective attentions and using appropriate strategy are automatized by repeated performances on problem-solving, which enable them to use their cognitive resources to the novel aspects of a problem (Schneider, 1993). With gained expertise, learners would no longer need to make cognitive efforts to understand the tool itself, but the cognitive functions of the learners and the tool should become well-coordinated to perform a task.

Representations

The ability to use external representations of knowledge and cognitive process plays an important role in the performances of many domains (e.g., Anzai, 1991). The internal structure of knowledge is often revealed and enhanced by the development of external representations, which learners use more efficiently with more expertise (Patel & Groen, 1991). Especially in science, one of the important inquiry approaches nowadays is to find patterns using visual representations, such as modeling and visualizations (Pagels, 1988). As a joint system, learners and the tool produce visual representations together, which are used not only to help others to understand their findings, but also to help themselves to reflect on their activities (Glaser, 1996).

RESEARCHING THE DEVELOPMENT OF THE JOINT LEARNING SYSTEM

This study intended to examine some of the assumptions about the joint learning system based on the above conceptual framework (a detailed discussion on this framework can be found in Kim & Reeves, in press; a relevant study can be found in Hay, Kim, & Roy, in press). First, cognition is distributed within a joint learning system during students' learning (Salomon, 1993). Second, the way a joint learning system develops through students' extended learning experience could be similar to the learning process of developing expertise by gaining knowledge structure, problem-solving strategies, and automaticity (Keating, 1990; Schneider, 1993; Winn & Snyder, 1996). Third, the primary expertise components of a person are knowledge, functions, and representations, and those of a joint learning system can be regarded as the same (Ericsson & Charness, 1994; Patel & Groen, 1991; Perkins, 1993). The main questions were: 1) How does the joint learning system develop intellectual partnership? 2) How does it gain expertise over an entire semester in scientific inquiry using the tool?

Research Set-up

As an undergraduate astronomy reform effort at the University of Georgia, the Virtual Reality Modeling Project (VRMP) implemented a unique learning approach to an introductory astronomy lab. It covers basic astronomy concepts of orbits, time, phases, eclipses, and seasons. This course is characterized by a modeling-based inquiry (MBI) pedagogical approach and a three-dimensional (3D) model construction tool called Astronomicon. Learners build and simulate their own models of solar systems within Astronomicon's 3D environment (see Figure 1). The learner-created models are used not only as surrogates of our solar system, but also as experimentations of nonexistent systems. Modeling tools become very powerful when students build models with underlying principles and dynamically modify them while running and observing them. Learners gain a fundamental understanding about the system through reasoning to make models and observing their created patterns (Kozma & Shank, 1998; Penner, 2001). Figure 1 shows the overhead view of the Earth (at the center) and the moon orbiting around the Earth—the big circle is the moon's orbital disk. Astronomicon modeling interface (Figure 2) facilitates learners' creation of models.

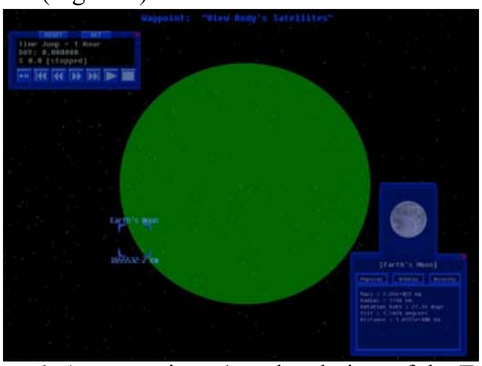

Figure 1. Astronomicon (overhead view of the Earth)

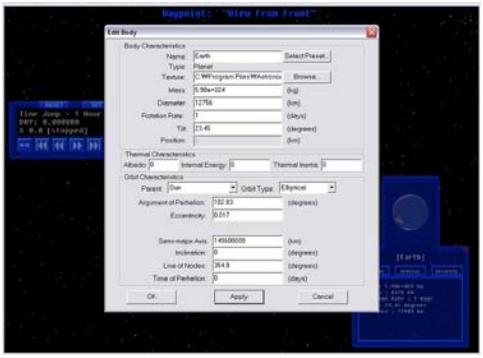

Figure 2. Astronomicon modeling interface

Learners worked collaboratively in pairs throughout the semester with an individual laptop computer. They usually used one of the computers for modeling and the other for information search within a group. In this study a pair of students was examined as a case to focus on the transitions and changes of their learning. The in-class observation was focused on the overall process, and the detailed interaction was analyzed using the video data. This required an in-depth investigation of the learning process and development, for which a complex digital system was used for data collection and analysis. Integrated Temporal Multimedia Data (ITMD) research system (Hay & Kim, in press) records, stores, and simultaneously plays the activity of each group, screen captures of the computer, and the voice of each participant. This approach provides unlimited access to the detailed interactions among learners and technology, maintaining a contextual richness close to the original. For this study a camera was set up for the group, and an extra camera was at the back of the classroom to capture any events happening beyond the group level. Other sources, such as learners' lab notes and written reports, provided a more complete understanding. The results of pre/posttests indicated overall improvements in basic astronomy knowledge. Test items were focused on light and planetary motion selected from three previously developed and validated tests: Force Concept Inventory (Hestenes, Wells, & Swackhammer, 1992), Project STAR-Astronomy Concept Inventory (Sadler, 1998), and the Astronomy Diagnostics Test (Zeilik, Schau, & Mattern, 1998).

Betty and Allen

The pairs were randomly formed or assigned at the beginning of the semester, and this group (Betty and Allen) was selected based on the overall attendance and the working relationship between the two. Even though learners were paired to work together, some chose to work individually, some dominated the work, and/or one of the pair had too many absences to make any contribution. The other factor of the selection was the balance between the two learners, including their confidence level, being co-ed, and interest and knowledge about astronomy.

Betty was taking the lab as her first college-level astronomy as a sophomore, whereas Allen was a senior retaking the course after several years. Both were social science majors. Betty was somewhat interested in astronomy whereas Allen read magazines and books about astronomy and was interested in furthering his understanding of the universe. Betty did not feel confident in the pretest, in which she correctly answered about 38 percent (the class average was approxiamtely 44 percent). Allen felt confident enough to do the lab work, but was uncertain about how well he did on the pretest (53 percent correct), which showed some misconceptions. Betty had the common misconception that the seasons are caused by the changing distance between the Earth and the sun due to the Earth's elliptical orbit around the sun. Similarly, Allen related the idea of Earth's tilt with the distance to sun (parts of the Earth would get closer when they are tilted toward the sun).

EVOLVING EXPERTISE AND PARTNERSHIP

The potential roles of the learner(s) and the tool as intellectual partners are implied by knowledge, functions, and representations embedded in the tool and the learner activities. The framework of the expertise structure guided the analysis within a meaningful chunk, such as modeling and observing lunar phases, exemplified in Table 1. Learners gather information to create their models, make decisions on the models and observations, and gain knowledge about the solar system. Learners use and produce various representations to assist their process. With the embodied rules, the tool provides the modeling interface that can collect and operate the inputs from learners. This knowledge and functions of the tool eventually contribute to the working representation of a system, which is continuously modified or viewed from different perspective throughout the modeling and observation process.

Table 1. The Expertise Structure of the Joint Learning System

	Learner(s)		*Tool (Astronomicon)*	
	Defined	*Example*	*Defined*	*Example*
Knowledge	Provided/Acquired information; prior/acquired knowledge and understanding	Data of the Earth and the moon (size, mass, etc.); cause of the phases	Rules embodied in the software	Three-dimensional configuration of the space
Functions	Decisions about modeling and observations; inquiry strategies	Observing the moon from the Earth; trial-and-error	Operations performed with learner inputs	Producing planetary motion of the moon around the Earth
Representations	Provided/gathered information materials; sketches/notes/reports; images from Astronomicon	Solar system data sheet; images of the moon going through phases seen from the Earth	Modeled system processed with learner inputs	Modeled reality from a specific viewpoint (the moon seen from the Earth)

Novices are characterized by their fragmented knowledge structure and weak approaches to the problems, which may turn their attention to tangential or unimportant aspects of the situation (Alexander, 2003). During the process of learning with Astronomicon, learners transform their fragmented factual knowledge from lectures and textbooks into an experienced one, situated in a coherent structure. During their initial model exploration with Astronomicon, Betty and Allen focused on surface features, practiced trial-error approaches, and depended on their common senses, as are characteristics of novices (Anzai, 1991; Patel & Groen, 1991). A typical mistake, coming from their underestimation of the space scale, was to make the distance between objects too short. Their initial models had objects being inside of their parent objects or orbiting in and out of it. They started changing properties, such as semi-major axis (the distance from the planet to its parent object) and eccentricity. Betty and Allen also maintained their interest on the surface features and their manipulations at the beginning. When first practicing model building, Betty made planets with various available planet textures and gave them cute names like Blue and Sharpie. When they first worked together and made four different Earths, Allen applied multiple kinds of Earth's textures to the planets (e.g., the Earth's topographical image, the satellite image with clouds, and images with different resolutions).

We explored the interactions within the joint learning system in order to understand the evolving expertise structure and overcoming novice traits. Working as a pair with one computer, learners also negotiated their roles within the team and went through the familiarization process with the 3D tool. We will focus our discussion on the growth of the expertise structure outlined above; nonetheless, the role negotiation and tool familiarization process are inherently part of the episodes. One of the constructs that determine the planetary motion of the solar system is *eccentricity* (the extent to which an elliptical orbit departs from a circular one. Eccentricity ranges between 0 and 1, 0 being a circle.). Eccentricity was the very first concept that learners explored in the class and continuously dealt with for their inquiry and was emerged as one of the main themes that continuously appeared. As one of the examples of the change in knowledge structure and inquiry approaches of the joint learning system, we will look at how Betty and Allen used, understood, and elaborated the concept of eccentricity.

Episode One: Making Meanings of Eccentricity

On the first day of working with Astronomicon, learners were asked to explore the differences made by changing the orbital eccentricity: *What is eccentricity?*

- Create a sun with four almost identical planets.
- The only difference should be the eccentricity.
- Explain the concept of eccentricity to your instructor using the taken data (pictures).

Before doing this activity, *eccentricity* (ε) was a word without much meaning, and its input values were numbers without any concept association. Watch Betty and Allen first started playing with Astronomicon:

1. [Betty keeps getting error messages when clicking on OK button, trying to finish adding a new planet. Error message: Please enter a number between 0 and 1.]
2. Betty: Huh… between 0 and 1… Is my eccentricity wrong? [currently 5]
3. Allen: Yes. Because eccentricity 1 means circle. To make it elliptical you have to make it less than 1.
4. Betty: Could be that? [putting in .00002].
5. Allen: You can try. I don't see why not. I guess that's the whole point of the program.

Earlier in class, Betty had trouble with her input for eccentricity [1-2]. Allen gave her the right value range (<1), but incorrect information that eccentricity 1 meant a circle [3]. Allen had a much better sense of the concept, knowing that eccentricity values had to do with shapes. At this point, however, the input of the .00002 value did not mean more than a random experiment to Betty, nor did to Allen [4-5].

Later, when they worked on the above task together, Betty and Allen started to make the connections between the numbers and the actual shapes of the orbits. Their initial model consisted of the four planets whose eccentricities were very close to zero (E1, ε=.01; E2, ε=.03; E3, ε=.05; and E4, ε=.07). All four planets were closely lined together, almost overlapping with each other [6-11].

6. Allen: I don't know what that did. I guess we will find out.
7. Betty: I guess maybe it is hiding behind another one, maybe.
8. Allen: Let's try... [making a new waypoint, E1 to E3]
9. [As he runs the model, E3 moves forward and backward from very close view and other planets are also seen from very close positions.]
10. Allen: What in the world?
11. Betty: I think they are running into each other...

A waypoint is a viewpoint defined by observer location and target direction. Learners choose where to "look from" and "look at" as in [8]. Using orbital disks, they realized that the differences among eccentricities values were not significant enough to have noticeable differences in orbits [12-16]. As they changed the values to have bigger differences, they saw the differences in shapes [17-21].

12. Betty: Maybe we should view it with the orbit thing. You know what I am saying?
13. Allen: Oh, ah, good! [going to the menu and turning on orbital disks for planets]
14. [As the orbital disk of each planet is turned on, the shapes of orbits show, which are all close to circles.]
15. Allen: OK, let's do this... actually make the eccentricities further apart.
16. Betty: OK, good call.
17. Allen: 'Cause it can be between 1 and 0, so we got a lot to play with.
18. Betty: And we will be able to see it better.
19. Allen: [modifying E2 (ε=.1)] Now, orbital disk... [turning on its orbital disk] Little bit better?
20. Betty: Yeah. [Allen changing the eccentricities of E3 (ε=.3) and E4 (ε=.8), turning on disks.] (Figure 3)
21. Betty: OK, the closer to zero, the more circular they are.
22. Allen: Yeah, it was zero, not the other way around.

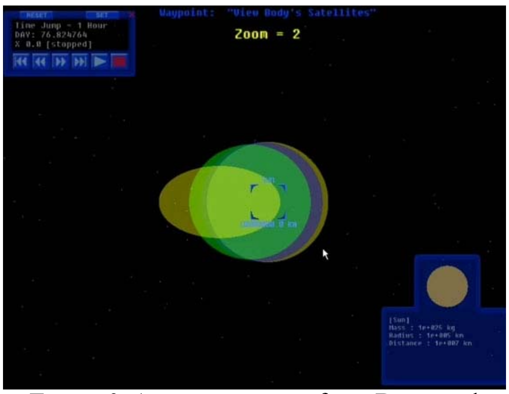

Figure 3. A screen capture from Betty and Allen's 09/08 video: Eccentricity pre-exercise

Table 2. Eccentricity pre-exercise

	Betty and Allen	*Astronomicon*
Knowledge	Eccentricity; Its values and orbit shapes	Underlying physics; Modeling interface; Eccentricity value range; Waypoint interface;
Functions	Decisions about input values/ observation tools (orbital disks)/perspectives; Trial-error approach (inputting/ observing/judging ε values)	Rule executions with learner inputs to create planets and create views for waypoints; Simulate motions of planets
Representations	Notes about the task on the board; Data taken from Astronomicon demonstrating differences in eccentricity (similar to Figure 3)	Modeled system with 4 planets; Visualized orbital disks; Waypoint, E1 to E3; Waypoint, Overhead view (Figure 3)

Here, Betty played a significant role in creating a meaning of eccentricity. She suggested utilizing visual representations of orbits [12-13], which enabled them to see the actual shapes of the orbits. This helped them to understand the eccentricity values [21]. Allen realized the information he provided earlier was incorrect [22].

Development

Through the process of working with new partners, definitional, numeral, and visual meanings of eccentricity started to be associated together in their knowledge structure. Allen played a main role of manipulating

Astronomicon, Betty facilitated their observation, and Astronomicon produced models and visuals with inputs. For this activity they used the most basic problem-solving strategy, which is trial-error approach. This activity allowed learners to take this weak method, with which learners start with no testing hypothesis and make claims based on pure observations of what is produced in Astronomicon with their uninformed inputs. They became familiar with using visual representations (orbital disks) by the exploration of one variable (eccentricity). These comprised their first step toward the development of expertise as summarized in Table 2.

Episode Two: Orbital Motion and Eccentricity

The subsequent four weeks (exercise 1 & 2) prepared Betty and Allen with basic modeling and observation skills and system variable knowledge (e.g., mass, distance, rotation rate, and orbital period). Their understanding of underlying relationships helped them to see the variables' relevance to the current observations. Building a model for exercise 3 (Orbital motion), Allen did bother to input some of the values accurately, such as size and rotation rate. They knew that most of the planets would look as small as dots when observing the orbital motions so that they only needed to focus on the values that would affect orbits, such as eccentricity.

In the following Betty and Allen had just finished making their initial model for an alternative theory on orbits: *All planetary orbits are quite elliptical*. By modeling and operating this theory, Betty and Allen gained knowledge about orbital motions and elaborated the concept of eccentricity. They first made Mercury ($\varepsilon = .3$), Venus ($\varepsilon = .4$), Earth ($\varepsilon = .5$), the moon ($\varepsilon = .3$), and Pluto ($\varepsilon = .25$), but did not see much difference among planets. They then changed the eccentricity of the Earth [23-24] and started seeing extreme effects [25-26].

23. Betty: They still look pretty circular.
24. Allen: I am going to actually change them more elliptical [changing Earth's eccentricity to .9]
25. Allen: [pointing to the screen] Look how close it is to the sun. It's actually inside of Mercury and Venus... 'cause it's point nine. [running the model] It's kind of crazy.
26. Betty: [watching the screen] Yeah... crazy.
27. Allen: [Earth moving from the far side of the orbit around the sun] See how slow it goes...
28. Betty: So where is the Earth now?
29. Allen: [selecting Earth and running and accelerating the model] Faster... I just want to see what happens when it gets back closer. It's going to be speeding up here. [pointing to the screen, the closest point of the Earth's orbit to the sun]
30. Allen: [Earth moving much faster closer to the sun] Shook! [stopping and resetting the model] I guess we need to do some waypoints actually.
31. Betty: Yeah. Well, hang on… OK, we are trying to prove that one of these is wrong and one of them is not. Oh, we probably take a picture of the Earth orbit with Mercury highlighted? So... 'cause you could see that that can't be how it really is because Earth would not be inside of Mercury.
32. [Allen nods his head and turns on the orbital disks of the Earth and Mercury.] (Figure 4)

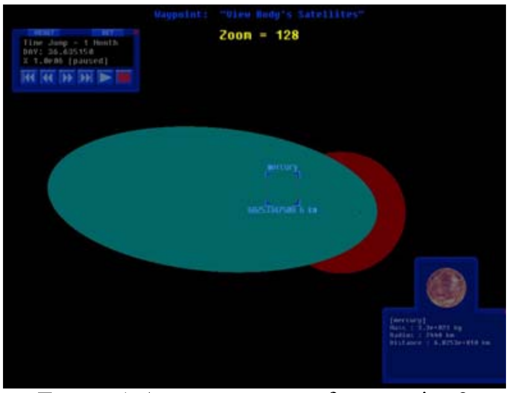

Figure 4. A screen capture for exercise 3 report by Betty and Allen: Eccentric planet orbits (Earth, 0.9; Mercury, 0.3)

Table 3. Eccentric orbit s and planetary motions

	Betty and Allen	*Astronomicon*
Knowledge	Eccentricity; solar system data; *changing speed on an orbit;* *orbital motions and relationships among planets*	Underlying physics; modeling input interface; *relationships among time and planetary motions*
Functions	Decisions about input values/ observation tools (orbital disks)/perspectives; *evidence-based claims (observing/finding evidence)*	Rule executions with learner inputs to create planets and create views for waypoints; *timed motions of planets*
Representations	Solar system data sheet; *data taken from Astronomicon to disprove the alternative theory (figure 4)*;	Modeled system of sun, Earth, and Mercury with modified eccentricities; *locating unobservable planets (blue box in Figure 4);* visualized orbital disks; waypoint, overhead view (Figure 4)

Beyond the relationship between the orbital shape and the eccentricity value, they realized the changes in Earth's relationships with other planets and the sun. The first thing they noticed was the changing position of the Earth in relation to Mercury and Venus, which was an important differentiating factor from the real system [25, 31]. Another observation was on the effect that the eccentricity had on the planet's speed of movement [27-30].

Development

From this episode we can find some indications for the development of distributed expertise. In Table 3 the expertise structure with this activity is summarized and these observable indications are especially italicized. They elaborated their knowledge structure by associating speed and positional relationships with the concept of eccentricity. They used less of basic trial-error approaches but observed with some expectations of the results [29]. The use of the representations is in support of their arguments, having clear purposes [31]. Specifically, timing became a highly relevant aspect of their observation because Earth with eccentric orbit can be inside of Mercury at one time, but outside of it at other times. Betty and Allen utilized the blue selection box in order to demonstrate this time element and disprove the alternative theory (Figure 4) [31]. Allen was more interested in how the model works, whereas Betty was more focused on how to use the images in order to support their claims.

Episode Three: Eclipses and Eccentricity

Learners show the qualitative and quantitative changes in their knowledge structure when gaining more competencies in a specific area (Alexander, 2003). When Betty and Allen made the four Earths with different eccentricities during the first episode, they did not know what they would get from that change. During the eclipses exercise (the ninth week from the first episode), however, Betty and Allen made changes to the parameters with certain expectations about the results because they became able to deduce possible effects or no effects on the phenomena. They brainstormed the changes they could make, disregarded the ones that would not affect the phenomena, and tested the ones that they expected to cause some changes. In the following episode they were about to reason about eccentricity as one of the variables for the frequency of solar eclipses [36].

33. Allen: If we change... how much the moon goes around the Earth, it might change…
34. Betty: OK…Rotation rate? No, that's rotation around the axis, isn't it? Oh, could we change the eccentricity to be smaller?
35. Allen: I don't know what that would do.
36. Betty: No, it wouldn't 'cause it is already almost circular. Or we could make the eccentricity bigger.
37. Allen: More elliptical?
38. Betty: It would reduce the number of eclipses, wouldn't it?
39. Allen: Do you want to make it really eccentric? [opening the Moon edit window]
40. Betty: Yeah, like point seven.
41. Allen: [putting in .7 and running the model from the moon to Earth view] Let's look and see what happens at 121.
42. [The timer count passes day 121 and they do not see any shadow going by.]
43. Allen: [stopping the model] No eclipse. So do you want to take a picture here when we do not have one?
44. Betty: I don't know. Let's wait until we see the first one. It might never happen.
45. Allen: Well, that's part of the question too.

They decided that a more elliptical orbit would change the frequency of solar eclipses and started making observations [36-41]. They checked the day (about 121 days) when they had the first solar eclipse in the real system [41-43]. They found that a more elliptical orbit would take a lot longer to have sun, moon, and Earth in line. Figure 5 is the image used in the lab report of Betty and Allen, which demonstrates the Earth and the moon were in line with the sun using orbital disks.

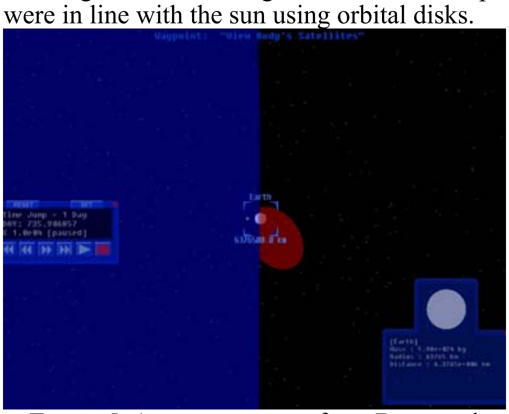

Figure 5. A screen capture from Betty and Allen's exercise 5: The moon (ε=.7) in line between the Earth and the sun

Table 4. Eclipses of planets with eccentric orbits

	Betty and Allen	*Astronomicon*
Knowledge	Eccentricity; *eclipses; planetary motion and light; relationships among planets (alignment)*	Modeling interface; waypoint interface; *relationships among time, planetary motions, and light*
Functions	Decisions about input values/ observation tools (orbital disks)/perspectives; *abstract deduction; time-relevant pattern observation*	Rule executions with learner inputs to create planets and create views for waypoints; timed motions of planets
Representations	Data taken from Astronomicon to show the rare alignment they encountered (Figure 5); *data taken from Astronomicon to show the Moon shadow cast on the Earth*	Modeled sun-Earth-moon system with highly elliptical orbit of the moon; visualized orbital disks; waypoint, overhead view of the Earth (Figure 5); *light effects; timer (day counts)*

Development

In this episode Betty and Allen associated another aspect (eclipses) to their knowledge of eccentricity. As emphasized in Table 4, they were utilizing Astronomicon's embedded knowledge about time, planetary motions, and light in order to understand eclipses' frequencies. They observed the patterns of the phenomenon as well as when things happened. As their problem-solving strategies, Betty and Allen deduced what would happen when changing certain variables without actually trying it out [33-38]. This indicates their developed understanding about inner workings of solar system. In their reports for this exercise, they used multiple image data taken from various perspectives in Astronomicon in order to show 1) the shape of the moon's orbit and its alignment, 2) the eclipse occurring seen from the Earth, and 3) the eclipse trail on the Earth, seen from the moon. This shows the culmination between Astronomicon's capabilities to represent modeled system from various perspectives and the learners' abilities to utilize the representations to support their claims and demonstrate their understanding.

Episode Four: Seasons and Eccentricity

Betty and Allen developed their knowledge structure about the solar system and various factors regarding its inner workings throughout the semester. Through the last exercise (seasons), they added another dimension (temperature/luminosity) to their understanding. They explored how the change in eccentricity affected seasons on a planet due to the variations on the orbit's speed and distance. Betty and Allen were able to abstractly reason through the model's operation based on their knowledge of inner workings. In the following episode they brainstormed to model an alternative theory of Earth's seasons: s*easons are influenced by the Earth's changing* *speed in its orbit*. Allen opened the edit window of the Earth (Figure 2) to think of different parameters to change [46-47]. He considered eccentricity because they had seen the speed variations from previous exercises [47-49].

46. Betty: Alright, how do you change the speed of the orbit?
47. [Allen selects the Earth, opens its edit window, and clicks on the eccentricity box.]
48. Betty: Now how would that change?
49. Allen: You see,... it has an average speed, but remember when it's really elliptical, it slows down when it gets away from gravity, and it gets faster as it goes close by it. [drawing an orbit with an index finger]
50. Betty: Right... now that would change it because that would make it go farther away from the sun?

After changing the eccentricity of the Earth from .02 to .7 and attaching an orbital path (Figure 6), they talked about other factors [51-53]:

51. Allen: OK, in order for it not to be affected by anything else but speed…
52. Betty: No tilt.
53. Allen: No spinning.
54. Allen: [changing the rotation rate from 1 day to 365 days] If it spins once every 365 days, then the same side is facing the sun 'cause it goes around in 365 days. [lifting his right hand as if holding a ball up; moving it from right to left and rotating it counterclockwise at the same time] Now, the same side is facing the sun… that means the other side won't get any…
55. Betty: Sun?
56. Allen: Right... so I don't think that would work.
57. Betty: Yeah, change it back to normal. [Allen changes it back to 1 day]
58. Allen: [watching the screen] With that elliptical orbit, I think it will still be the same. (see, Figure 6)
59. Betty: You mean, seasons?
60. Allen: I mean the tilt... if the Earth is that close to the sun [pointing to the right part of the orbit], it will still burn up, and here it will be super cold [pointing left, away from the sun].
61. Betty: So, the summer will be much shorter than the winter.

Allen thought about the rotation of the Earth as a factor. Without observing the model, however, he was able to dispel that idea by reasoning through it using his hand as a representation [54-57]. As Betty had the knowledge that the tilt affects the seasons on Earth, she considered it to be the main factor [52]. They finally came to realize that the tilt should no longer matter in a different condition (extremely elliptical orbit) [58-61].

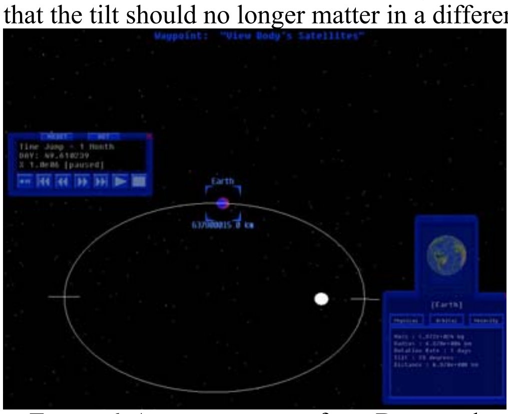

Figure 6. A screen capture from Betty and Allen's exercise 6 reports: The Earth (ε=.7) with its luminosity pattern and orbital path

Table 5. Seasons of planets with eccentric orbits

	Betty and Allen	*Astronomicon*
Knowledge	Eccentricity; changing speed on an orbit; *cause of seasons; tilt of the Earth*; *changing distance to the sun; lengths of seasons*	Modeling interface; relationships among time, planetary motions, and light; *luminosity*
Functions	Decisions about input values/ observation tools (*orbital paths, pattern visualization*) /perspectives; abstract deduction; time-relevant pattern observation	Rule executions with learner inputs to create planets and create views for waypoints; timed motions of planets
Representations	Data taken from Astronomicon demonstrating differences in eccentricity (Figure 6); *Hands*	Modeled sun-Earth system with a highly elliptical orbit; *visualized Earth's orbital path; luminosity pattern visualization;* waypoint, overhead view (Figure 6); timer (day count)

Development

We can infer that the intellectual partnerships of Betty and Allen with Astronomicon had changed throughout the semester. They were less dependent on pure observations for their reasoning and more dependent on the knowledge structure that they gained by working with Astronomicon. Betty and Allen approached their tasks through a different kind of thinking; they were asking, "What value can we change to make a certain thing happen?" instead of "What happens if we change this value to something else?" For the former they needed to know the underlying principles, but not for the latter. This kind of abstract reasoning is possible only when learners have the coherent knowledge. Emphasized in Table 5, eccentricity became a relevant concept with tilt, distance, and speed in relation to cause and lengths of seasons. During this time Betty and Allen chose to use orbital path instead of orbital disk in order to see better and did not bother to add texture for the sun (Figure 6). This indicates that they were now focused on using representations in support of their inquiry.

FACILITATING THE DEVELOPMENT OF JOINT LEARNING SYSTEMS

The above account illustrated the process of a group's gaining expertise and developing the partnership as a joint learning system. The complex process of their development was reconstructed and exemplified with the concept of eccentricity with four episodes. Overall, Betty and Allen started the semester as novices in their skills for inquiry and the tool with some differences in their interest and knowledge levels. As a team, they gradually gained expertise in modeling-based inquiry, and clearer knowledge and mental models about the solar system.

From the perspective of expertise theory, Betty and Allen showed their progress in their knowledge structure, problem-solving strategies, and automaticity (Keating, 1990; Schneider, 1993; Winn & Snyder, 1996). Through investigating phenomena by building and testing models each week, they associated the underlying principles of the solar system with their understanding of the Astronomicon models' inner-workings (knowledge structure). Their inquiry strategies moved from trial-error approaches toward more focused inquiries of making predictions and devising Astronomicon features to understand relationships (problem-solving strategies). They gradually found their roles in this team and internalized their inquiry process as well as the procedure of building and observing models (automaticity). As exemplified in the episodes, the gains from each week became important foundations for their performance in the following week, making their partnership stronger little by little.

The changing pattern of knowledge structures for Betty and Allen was consistent with the changes indicated in expertise literature moving from a more fragmented knowledge to a more cohesive and deeper one (Alexander, 2003). Betty and Allen's knowledge about astronomy was initially based on their common sense and some bits from their former science classes. They were dependent on the Astronomicon interface to know the needed input variables without understanding what each value meant for the model. They gradually gained a better knowledge structure of the solar system and learned how some of the values related to model properties such as eccentricity to orbital shape. The way they worked with Astronomicon and conversed during the class indicated cohesiveness in their knowledge structure. They often recalled some values that were frequently used and differentiated some of the factors that would not affect their current modeling and observations from the relevant ones.

They came to better understand the fundamental relationships among underlying factors and their effects on the patterns of planetary light and motion. Their knowledge was constructed in a situated manner; that is, it was used, tested, and visualized within their modeling activities. They broadened the observer's viewpoints as they investigated from one planet to another and even from (or to) specific spots on a planet. Betty and Allen's improvement as novice scientists can be also noticed from their maturity of writing their lab reports, which moved from demonstrating their creation of model to making evidence-based claims with collected image data from Astronomicon. In their posttests Betty made 29 percent of improvement (67 percent of correct answers) and Allen made 20 percent of improvement (73 percent correct).

Through Betty and Allen we saw a joint learning system in action, partnering and evolving. The designed curriculum had supported the process of gaining expertise in modeling-based inquiry for basic astronomy. Both learners became confident in and good at their tasks and roles, and their report grades started as average and reached perfect points. Betty and Allen, however, had multiple challenges, had some concepts never completely clarified, and had inquiry strategies not fully internalized. Betty and Allen, unfortunately, did not expand their understanding about the solar system much beyond the sun-Earth-moon system. For their last activity in exercise 6, seasons, they first experienced how Venus would be different from what they had been modeling and observing mainly with the Earth and the moon. Their standard conceptions of time, such as day and night, seasons, and year, were completely overthrown by making the factual numbers of Venus take action in Astronomicon. However, this activity became the very last one that they briefly encountered. Astronomicon was designed in a way that allows a learner to expand his or her perspective centered on the solar system, and such activity could be easily incorporated with any current tasks.

The baseline activities need to be more focused and expanded in order for learners to have fundamental understandings of underlying relationships, not just within our sun-Earth-moon system, but beyond. Focused activities, such as investigating the factors that affect the lengths of a day—not only for Earth's day, but also for days of other planets, would engage learners in exploring with their models and have an experienced and solid knowledge structure. Another challenge that needs to be addressed is learners' lack of engagement in the scientific discourse using right terms and theoretical underpinnings. In addition to making connections among various phenomena with eccentricity, some theoretical discourse including, aphelion/perihelion, Kepler's third law, and foci of elliptical orbits, should be more tightly embedded within their inquiry activities.

CONCLUSION

Through this study, we have gained a deeper understanding of the process whereby a pair of learners develops their intellectual partnership with a cognitive tool for scientific inquiry. We found that all the successes as well as the challenges that they had were interrelated throughout the semester and that each success or challenge has its own individual history. In order to better facilitate cognitive partnerships, the tool and the activities should support gaining expertise on the aforementioned aspects. In other words, the tool should be designed in a way such that its capabilities are apparent, not hidden to the learners, and the activities should support mastering those features in addition to addressing important concepts. Why the learners interact in a particular way could not have been explained without considering learners' histories, because every action they took was the consequence of their prior interactions with the tool and with each other (Hutchins, 1995). The future research on intellectual partnerships of joint learning systems should be expanded to comparing groups with distinctive characteristics, as different learners will form different joint relationships.

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Review of Computer-Mediated Collaborative Concept Mapping: Implication for Future Research

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Abstract. In this paper we critically review and analyze previous research on collaborative concept mapping in both face-to-face and networked environments. Although research has shown the positive effects of collaborative concept mapping on learning in face-to-face learning environments, there is a dearth of research which specifically focuses on the potential value of adopting collaborative concept mapping in online learning environments. Newly developed concept mapping software which operates via the Internet makes it possible for distance learners to implement concept mapping as a learning tool for co-constructing knowledge. Using our analysis of current research we provide some directions for future research in the use of concept mapping for online learning.

Keywords: concept mapping, collaborative learning, computer-mediated learning, literature review, assessment

INTRODUCTION

A concept map is a visual representation of knowledge organization that consists of nodes for concepts and links for their relationships (Novak & Gowin, 1984). Educational psychologists believe concept mapping helps people construct conceptual knowledge through externalizing and organizing their implicit knowledge (Jonassen, 2000). Students also report that the activity of developing concept maps helped them learn better because the resulting maps provide external graphical representations of their internal knowledge (De Simone, Schmid, & McEwan, 2001). In addition, collaborative concept mapping has been recognized as an effective strategy for instruction and learning because it requires students to negotiate the meaning of concepts and propositions until all group members agree (van Boxtel, van der Linden, & Kanselaar, 2000). In other words a map serves as a conscription device (Roth & Roychoudhury, 1992) for collectively externalizing mental ideas, which provides a context for sustaining discourse.

According to Vygotsky (1978), an individual's cognitive development is highly affected by one's social relationship with others. He argues that a student reaches his or her *zone of proximal development* (ZPD) – the distance between an individual's actual development level when learning alone and the individual's potential development level with help of adults or advanced peers – through social negotiation and collaboration. During the collaborative concept mapping process, all group members have a chance to listen to each others opinions and arguments about concepts and propositions. Thus we argue that collaborative concept mapping should help students reach a higher level of understanding which may not be obtainable if they draw a map alone.

Despite research identifying the positive effects on cognitive learning outcomes from using concept mapping activities (Komis, Avouris, & Fidas, 2002; Liu, 2002; Stoyanova & Kommers, 2002), concept mapping has been considered time-consuming in terms of drawing, modifying, and assessing a map because people traditionally created concept maps with paper and pencil, and were forced to count the nodes and propositions manually (Chiu, Wu, & Huang, 2000b). Recently, several computer applications (e.g. Inspiration, CMap, Semantica) were developed to support computer-mediated concept mapping which makes the modification of concepts and links easier. In addition, several networked concept mapping applications have the capacity to facilitate geographically separated students share or construct maps together. For instance, CMap is a concept mapping tool which enables students in different places to share their own concept maps. Networked Concept Mapper used in Chung, O'Neil, Herl, and Dennisi's study (1997) supported students to construct maps together by synchronizing all networked computers if any changes are made and by enabling students send a message to each other.

Much of current distance education has been criticized as a replicate of conventional lecture-based classroom education, in which students learn individually with little interaction among peers (Gunawardena & McIsaac, 2004). We believe that networked collaborative concept mapping provides distance learners with opportunities to experience multiple perspectives of others and support for social negotiation processes of knowledge co-construction. However, little research on the use or value of computer-mediated collaborative concept mapping (CCM), especially in online learning environments, has been reported. The purpose of this paper is to review current research on CCM and provide suggestions for future research on computer-mediated CCM. Fourteen empirical studies were selected through searching several academic research literature databases (e.g. Eric, PsycInfo, ESBCO, and ArticleFirst) by using key words including collaborative concept map or mapping.

Table 1 Empirical Studies Reviewed

Category	Face-to-Face CCM	Networked CCM
Empirical Studies	van Boxtel, van der Linden, & Kanselaar (2000)[a]	Chang, Sung, & Lee (2003)
	Coleman (1998)[a]	Chiu (2004)
	Czerniak & Haney (1998)	Chiu, Huang, & Chang (2000a)
	Gilbert & Greene (2002)	Chiu, Wu, & Huang (2000b)
	Ledger (2003)[a]	Chung, O'Neil, Herl, & Dennis (1997)
	Liu (2002)	Komis, Avouris, & Fidas (2002)[b]
	Stoyanova & Kommers (2002)	De Simone, Schmid, & McEwen, (2001)

[a] Technology was not used to mediate CCM. [b] This study consisted of face-to-face learners and distance learners.

ANANLYSIS OF PREVIOUS EMPIRICAL RESEARCH ON COLLABORATIVE CONCEPT MAPPING

According to Jonassen (2000), a concept map can function as a learning tool in four ways: a study guide, a knowledge integration tool, a planning tool, and a tool for assessing what learners know. We found that most studies of CCM in educational settings focused on using a concept map as a social thinking tool (Roth & Roychoudhury, 1992) integrating the functions of a knowledge integration tool and an assessment tool to assess either a collaborative concept map as an end product or collaborative concept mapping as a process or both. Roth and Roychoudhury (1992) argue that considering a concept map as a product is only useful for assessing the product of knowledge co-construction while considering CCM as a learning activity is an ideal tool for assessing the process of meaning negotiation. Further, they suggest that the process of concept mapping as a group activity may be more important than the concept map itself. A map is only a final product but the real learning happens during the process of negotiating, elaborating, and justifying propositions. Therefore, when researchers investigate the effects of CCM, it is necessary to examine not only maps as products but also the meaning negotiation process.

We also noticed some similarities and differences among the research contexts. The group sizes in almost all studies were either dyads or triads. Small groups tend to form a comfortable environment for students to express their ideas for knowledge co-construction and to provide one another with social support (Stacey, 1999). In addition, it seems that dyads or triads are a manageable group size for most CCM activities. We found there are three forms of map creation discussed in the research literature: face-to-face computer-mediated CCM, synchronous networked CCM, and asynchronous networked CCM. While most face-to-face CCM research was conducted in real-life classrooms, almost all studies of networked CCM were conducted in laboratory settings. Specifically, participants were brought into the lab, assigned into small groups, and required to construct a concept map collaboratively only by communicating through networked computers within limited time. Thus, most of the laboratory research findings reported in the literature on how concept maps are constructed collaboratively is not easily generalized into real world learning situations.

Since there is little empirical research on computer-mediated CCM and the nature of task is similar to face-to-face CCM, in our review we included several face-to-face CCM studies in our analysis as long as they were empirically-based and participants were required to create a concept map collaboratively. As a result, we have identified four issues: assessment on a concept map as a product versus CCM as a process, various effects of CCM, scaffolding strategies used in concept mapping, and implementation issues of CCM tasks.

Assessing a Concept Map as a Product and Collaborative Mapping as a Process

In order to assess the effect of computer-mediated CCM on students' learning outcomes, some research simply examined a collaborative concept map as an end product. However some studies also examined the collaborative mapping process in addition to the end products (the maps). Also, we noticed that some researchers were interested only in the group learning outcome; in addition, some researchers were interested in the knowledge gain on an individual level as well.

A scoring scheme was the most commonly used assessment method when a group concept map was used to reflect the group learning outcome. Chiu, Wu, & Huang (2000b) machine-scored students' group maps using a revised scoring scheme originally developed by Novak and Gowin (1984) to examine the components and structure of the maps. In other studies, an expert map was added as a criterion and was compared to group maps using a scoring technique developed by Herl et al. (1996) by examining the similarities and differences between maps in terms of the number of concepts and propositions used and the complexity of the organizational structures (Chung et al, 1997). Rye and Rubba (2002) used a statistical correlation approach to represent the similarity between an expert map and group maps.

In order to fully understand the knowledge co-construction process in a group, some researchers also examined the CCM process. In van Boxtel et al.'s study (2000), students' interaction was coded into utterance and learning episode levels to investigate the discussion about propositions and the conversation on question, conflict, and reasoning among peers. Chung et al. (1997) approached analysis of the CCM process in a different way by examining which message types (i.e. adaptability, coordination, decision making, interpersonal, leadership, and communication) during the collaboration were most effective in creating a better concept map. Chiu et al.'s study (2000b) focused on what process each group took to complete a concept mapping task in a networked CCM and how those different interaction patterns influenced the group concept maps. They found that the group focusing on generating one or two propositions and progressively expanding the map created a better concept map than other groups using the other interaction patterns.

A desired group learning outcome does not guarantee that each individual in a group learn equally well. To assess individual internalization, Stoyanova and Kommers (2002) examined whether the concepts appearing in the group map also transferred to individual maps created one week later. An alternative way was to require them to do an individual task reflecting their level of integration of concepts in CCM (Gilbert & Greene, 2002) or take objective tests about the topic used in CCM (van Boxtel et al., 2000). In this case, the researchers wanted to examine an individual's level of understanding transferred after collaboration.

The Effects of Collaborative Concept Mapping

The effects of CCM have been researched in both the affective and cognitive aspects. CCM was found to have no significant effect on science self-efficacy of female eight grade students (Ledger, 2003) and on pre-service teachers' self-efficacy on learning and teaching physical science (Czerniak & Haney, 1998). However, pre-service teachers who constructed a concept map with Inspiration in a group reported a lower anxiety level on learning and teaching physical science than those who had not constructed a concept map at all.

From a cognitive aspect, pre-service teachers in a CCM class outperformed those in an expository class in the final exam which tested students' level of understanding of physical science concepts (Czerniak & Haney, 1998). Another example can be found in Stoyanova and Kommers' study (2002) in which they report undergraduate students outperformed counterpart students in solving ill-structured problems when they constructed CCM together. Gilbert and Green (2002) also reported that students in a group, who actively engaged in constructing a concept map, integrated concepts from the map into their final individual projects much better than those in groups in which a group concept map was done either by "sewing" divided individuals' works or by only one member. Since almost all the studies above were done in face-to-face environments, we are not sure similar research would produce the same results in online learning environments. More empirical research on the effects of CCM in online settings would provide valuable information for online educators and online instructional designers.

Scaffolding Strategies Used in Concept Mapping

Previous research adopted and implemented a variety of ways to shape or scaffold students' concept mapping activities. Several research experiments provide students with predefined concepts, relations, and message types in order to help them focus on the core concepts of a topic and promote the collaboration process (Chiu, et al., 2000a; Chiu, et al., 2000b; Chung et al., 1997). Another type of scaffolding strategy was using explanation prompt questions (Coleman, 1998). During the mapping and problem-solving process, group members took turns as a prompter and asked other group members to elaborate their justifications of propositions and solutions they suggested. A sample prompt question included, "explain why you believe that your answer is correct or wrong." The explanation prompt questions were used to force the students to elaborate their thinking in order to promote discussion among students.

The findings from aforementioned research indicates that limiting message types hindered students from deeply engaging in discussion about the content because they had to spend considerable amount of time in selecting a message (Chung et al, 1997). In contrast, the explanation prompt questions embedded in the concept mapping and problem solving process had a positive effect on students' usage of intuitive and scientific links for both the individual and collaborative performance (Coleman, 1998).

Implementation of Collaborative Concept Mapping Task

Several issues related to the implementation of CCM tasks have been identified. Students should be prepared for the topic which they will construct on a concept map. Chung and his colleague (1997) reported that students could not deeply engage in the task because they were not familiar with the topic itself. Students should be provided with a sufficient training on how to create a concept map and use a concept mapping tool in order to make sure they have necessary skills to perform the given task. In addition, possible technological problems should be identified and solved prior to engaging students in the task. For instance, the cross-platform compatibility issue of mapping software needs to be taken into account. In the De Simone, Schmid, and McEwan's study (2001), students encountered technical difficulties with PIViT, which is a PC-only concept mapping tool, and thus switched to use Inspiration in the middle of the course.

Students should be guided on how to collaborate effectively and efficiently. In van Boxtel at el.'s study (2000), groups in which members prepared concepts individually before engaging in the CCM created better concept maps and asked more questions to each other than groups in which member did not prepare anything before collaboration. Another related issue is the use of management mechanisms, or authorship, in co-constructing a map together. It can be problematic in networked CCM when members try to modify a map simultaneously. Chiu (2004) suggested four protocols of managing networked CCM in a synchronous situation: assign, rotate, give, and open protocols. Although he found that the assign protocol, having one member responsible for mapping manipulation and the other members responsible for observing or commenting, was superior to the other management protocols in managing the process, we need more research in this topic. We also found from the review that 'collaboration' can be interpreted differently by students. In Gilbert and Greene's study (2002), when students were asked to construct a concept map collaboratively by adding at least 5 concepts per person, each group took various ways of collaboration either by dividing tasks and sewing them together, letting one student to complete a map alone, or actively constructing a map together through social negotiation of meaning.

CCM takes time because it requires a group to do decision-making together. Several studies, especially the laboratory ones (Chiu, et al., 2000a; Chiu, et al., 2000b; Chung et al., 1997), required a group of students to build a concept map in a relatively short period of time, less than one hour. To be more realistic, a group of students should be allowed to build a concept map in a reasonable time frame because CCM requires students to make decisions together through social negotiation.

CONCLUSION

Based upon the analysis of previous research on computer-mediated CCM, we have identified four suggestions for further research. The best way for researchers to investigate the true effect of CCM, is to assess the process of CCM along with examining the end product (the concept maps) because it more likely will illuminate how the collaboration process influences knowledge co-construction. Driscoll (2001) argued that assessment of CCM as a process is a more productive line of research. Also, Stoyanova and Kommers (2002) supported their idea by arguing that learning effectiveness depended not only on the result but also on the learning process taking place via social interaction.

Individual internalization should be also assessed as well as group outcomes. Although group maps show group members' consensus on the meanings of concepts and propositions, we cannot assume that all the members in a group would end up with the similar level of understanding and knowledge (Roth & Roychoudhury, 1992). Individual cognition is the interplay between situations where group members construct meanings together through social negotiation and where individuals actively construct his/her own meaning.

We also agree with Johnson and Johnson (1994) that individual accountability should be ensured in collaborative tasks to prevent free riders. Little research, however, actually examined individual accountability. Gilbert and Green (2002) required groups of students to submit group reflection papers reflecting group working process. Also, peer review is a widely used technique to ensure or encourage individual accountability.

Newly emerging technologies enable researchers to study CCM even with distance learners, and to track students' dialog and their concept map development process. For example, Networked Concept Mapper used in Chung et al's study (1997) and Representation 2.0 used in Komis et al.' study (2002) support a function that students can build a concept map collaboratively even in a distance by sharing screens and text-based chat-rooms which can be saved easily for further content analysis.

Finally, the implementation process should be cautiously designed and monitored. Students can interpret 'collaboration' differently. For instance, several groups in Chang, Sung and Lee's study (2003) submitted a group map by selecting the most complete individual map and revising it. In Czerniak and Haney's study (1998), individuals' maps were combined and submitted as a group map or one member did almost all the work. We hope that our review will provide some directions for more productive research in the use of concept mapping for online learning.

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Weak Guidance with "Look" Functionality in Handheld-Based Classroom Activities

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Abstract. Wireless handheld technologies can be used to move technology into the classroom framework rather than to move classrooms into the technology framework. To make such technologies effective, we support activities and teaching practices crucial to children's creativity and competence. However, because of the small screen size and distributed nature of some of the activities, it can be hard for teachers to engage in *formative assessment*, that is, finding out what students know and can do. The current work reports an idea about how to solve this problem and the first assays of this idea in the classroom. We try to enable what we call *weak guidance* during collaborative activities, by implementing a system feature called "Look."

Keywords: Mobile Computing, Constructivist Pedagogy

INTRODUCTION

Ms. Smith was using a handheld-based math activity called "Match-my-Graph" with one of her eighth-grade classes. Students were grouped into pairs. Alice drew a line on an animatable velocity graph on her handheld. Brian's goal was to produce the equivalent function on a position graph on his handheld. To do this, he beamed each of his guesses to Alice, who gave him progressively more refined hints, until the graphs described the same trajectory. The challenge was for Alice to devise useful hints describing position change based on the relationship between two velocity graphs, and for Brian to interpret velocity-based hints in terms of required changes to the position graph. In this case, Alice had the hypothesis that velocity graphs below the x-axis meant that the object had a negative position, leading to systematically incorrect hints. Both students were becoming frustrated when the teacher came by. She watched them argue about whose mistake it was. She glanced at one screen, when the student was not drawing or beaming. Then she said, "Is everything all right?" Both students responded yes. She moved on. Ten minutes later, they were still working on the same problem when time ran out, each quite distressed at the failure of the other.

This scenario is taken from a month-long intervention using NetCalc with 8th grade students, which showed considerable gain scores and, even achievement on qualitative AP-calculus problems (Tatar, Roschelle, Vahey & Penuel, 2003; Vahey, Tatar & Roschelle, 2004). The class wide consequences of the study were overwhelmingly positive; therefore, arguably, the time the students spent struggling on the problem was well spent. However, at the same time, compared to when observing the use of manipulatives, worksheets or desktop, the teacher's ability to gauge the nature and seriousness of the problem was curtailed. Wirelessly-connected handheld PDAs hold great potential for the classroom because they are portable, easy-to-maintain and relatively inexpensive (Tatar, et al, 2003; Soloway, Grant, Tinker, Roschelle, Mills, Resnick, Berg & Eisenberg, 1999). It may be affordable to provide a handheld for every student, when it is too expensive to provide a desktop computer or too bothersome to go to the computer lab.

Handhelds can be used many ways in the classroom. For example, employing both handhelds and large screen displays, Wilensky and Stroup (2000) use a distributed programming language, StarLogo, to allow students to explore complex distributed systems. Kaput and his colleagues (Kaput and Hegedus, 2003; Kaput, Roschelle, Vahey, Tatar & Hegedus, 2003) also emphasize aggregation activities, highlighting the individual's contribution to the whole class. In these situations, there is a relatively close relationship between the acts of individuals and their publication to the whole classroom, including the teacher. This publication provides opportunity for formative assessment. However, another class of activities involves a slightly longer tether. For example, students may develop complex and sophisticated idea-networks using Picomap, a concept-mapping tool, before uploading them to a desktop or large screen formats (Luchini, Quintana, Krajcik, Farah, Nandihalli, Reese, Wieczorek & Soloway, 2002). Likewise, the Sketchy tool (www.goknow.com) and elaboration in

ImageMakers (www.projectwhirl.org) allows students to produces animations of science processes. Indeed, ImageMakers has formative assessment as a goal; nonetheless, it primarily supports uploading at the end of the activity, using HotSyncing. In the NetCalc project, activities moved between whole class, small group, and individual work. The students had a clear idea when they had finished the tasks, but there were barriers to fine-grained formative assessment (Davis, 2002).

In this paper, we describe the beginning of an investigation of how formative assessment can be integrated into the classroom using Infrared-based (IR) communication (e.g. beaming). We focus on IR in this work for the same reasons we used it in the NetCalc project: IR machines are less expensive, and require no server. On the other hand, any success we have with implementing formative assessment tools with IR should only be amplified with radio-frequency (RF) communication. Since, unlike IR, RF is not directed at a particular other person, overhearing can be accomplished less intrusively.

To abstract the issue of overhearing, we created a game that is an electronic variant of the Tangram game so widely used to explore the creation and maintenance of common ground in the CSCW and psycholinguistic literature (Clark, 1996a; Clark, 1996b). Indeed, the NetCalc Match-My-Graph activity was based on the structure of the Tangram game. Like Tangrams, our game involved two participants, a matcher and a director. For each round, the director had a sequence of images in a new random order. The matcher also started with the same sequence of images in a random order. By discussing each one in turn, the matcher was able to put the images on his screen into the same order (see Figure 1) as the director. The game is complete when the matcher and director agree that they have the images in the correct order. In our game, KCM, the images were Korean characters. The KCM game system runs on a Palm OS handheld computer and uses a stylus for drag and drop characters from one place to another and to initiate task actions, such as “shuffling” the image order.

Figure 1. Korean characters matching (KCM) game

WEAK GUIDANCE WITH LOOKING IN CLASSROOM ACTIVITIES

KCM is a coherent activity in which participants are trying to understand what the other one is talking about, in other words, in which they are learning. However, the purpose of our study was to investigate another feature, *Look*. In activity-based classroom environments, the ideal teacher has often been characterized a “guide on the side” rather than a “sage on the stage” (National Research Council, 2000). This pedagogical goal is based on the idea of constructivism, that active engagement in knowledge creation is vital to deep understanding. From a psycholinguistic point of view, teachers engaged in coaching would ideally be characterized as “side participants” to the interaction they are observing. Their job is to assess and provide weak guidance, not to distract the students from their focused work. Typically, side participants enter in to a conversation about an object by watching the interaction until they can make an informed contribution. Of course, it is the teacher’s prerogative to ask students for an explanation of what they are doing, but typically, she picks her moment. Additionally, KCM provides a chance for the teacher to introduce secondary information, including the names of the Korean character

Look supports formative assessment by allowing the teacher to capture objects from other screens by beaming to them (Figure 2). Instead of having the owner of the information beam stop on-going activity to beam to the newcomer, the newcomer could request data from the students’ handhelds without disruption.

In our project, *Look* was implemented using *Exchange Manager* in the Palm OS API. The Exchange Manager provides a high-level interface to use the *exchange* socket structure. We embedded and tested this *Look* functionally as a component for the KCM game.

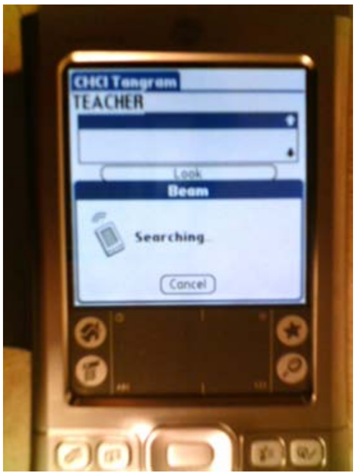

Figure 2a. Initiating a *Look* to capture data from student's handheld.

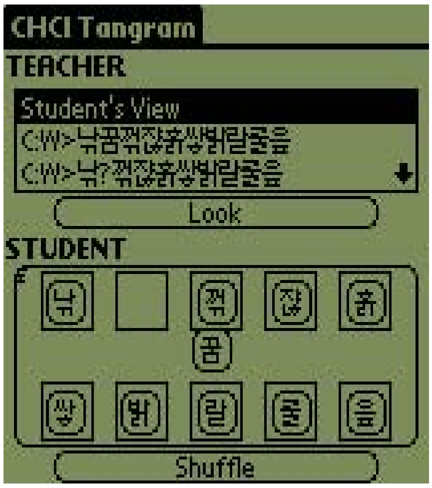

Figure 2b. What the teacher sees after a *Look*.

PROOFS-OF-CONCEPT

In April 2004, during the annual *Women in Computing Day* at Virginia Tech, eight local middle school girls (ages 12-14) experimented with our application and *Look* functionality. They were divided into three groups of two "learners" plus two student "teachers." One "teacher" monitored two matcher-director groups at the same time. "Learners" switched between matcher and director roles in different rounds. The teacher's system was equipped with both *Look* and a paper list of Korean characters and corresponding English-language names. The teacher was instructed to try to figure out whether the groups were making progress and to help them if they got stuck. The experiment was conducted in a large meeting room with tables set in a U-shape. Students were not instructed on where to sit or whether they were free to move around. Nonetheless, learners sat facing one another or around a corner of the table while teachers sometimes stood next to one of them, sometimes say next to one of them, and moved from person to person.

Notes were taken by three observers to document the interaction. These focused on whether and how *Look* was used. Participants were asked to engage in a "think-aloud" process in which they articulated what they were doing and when to enable us to locate usability problems. Afterwards, students were asked to indicate both the positive (good) and negative (bad) aspects of what they had done.

Given its similarity to the Tangram and Match-my-graph games, it was not surprising that Matchers and Directors appeared to be engaged and consistently expressed enthusiasm. The teacher's role was the new component. These students did seem engaged, but not always in the ways we had envisioned. One teacher functioned much as we imagined, looking over the matcher's shoulder and beaming to a director to check desired the target order. This teacher beamed a lot in the middle of the game; however, the other beamed only at the beginning and end of each round. Thus, she was not monitoring progress the moment, but only global progress. Worse, neither teacher was able to intervene effectively during the interaction. Instead, they spoke with learners only after they had reported the end of their play. At that point, the teacher would check again with beaming and give feedback to students, such as concerning the incorrect placement of characters.

Subsequently, six triads of male undergraduate and graduate students at Virginia Tech were recruited through email requests to undergraduate and graduate researchers in Human-Computer Interaction (HCI) to perform an almost identical task. The average age of these participants was 24.7 years (Standard Deviation (SD): 3.7). All students were from the School of Engineering, primarily computer science and industrial systems engineering. Half of these triads had *Look* functionality for the teacher, and half did not. Each group participated in two rounds of KCM, rotating all participants between roles. Participants were videotaped and log files of the interaction were kept. Additionally, two kinds of simple learning outcome measures were obtained: participants were asked to pick out which ten characters they had worked with from a list of the complete 20-character Korean alphabet, and to match characters with English names.

Although there were too few groups for statistical tests to be meaningful, the number of errors in recognizing the characters was consistently less for the groups that had *Look* compared to those that did not. In round 1, the mean number of errors in recognition with *Look* was 7.33 (SD: .99) while without *Look*, it was 10.67 (SD: 2.18). In the second round, the scores were 2.67 (SD: 1.33) and 8.33 (SD: 4.84). Note that the standard deviations are also smaller for the groups with *Look* than for those without. Additionally, students in the *Look* condition were more accurate in naming the characters after round 1, though not for round 2.

Videotape and log files revealed that teachers with *Look*, updated and consulted their handhelds quite frequently. One teacher looked at the others' screens ten times during one round. He moved back-and-forth between looking at the matcher's and director's screens. Other teachers in the *Look* condition beamed to get the director's order and then sat next to the matcher and watched him work.

Although there was no reason to believe that the participants had any familiarity with pedagogical theory, and no instructions were given to the participants about the kind of pedagogy desired, participants in both conditions commented on the teacher's role. One, in the *Look* condition, said "The teacher must not help the students until the last minute. Extensive help from the teacher will reduce the learning." Another commented "We can keep going even if the teacher does not say anything." On the other hand, students in the no-*Look* condition, commented that the teacher was not particular useful. One said: "As far as the teacher's action, it was minimal, actually non-existent when I was trying to match for pictures." Another echoed something sometimes heard from students in project-based classes that "the teacher did not have to help in solving the puzzle, we just did it ourselves."

DISCUSSION

Thus, we have some support for the idea that Look functionality can be useful in conjunction with at least this task. The undergraduate and graduate student teachers appear to have used it in a way consistent with our pedagogical hopes and goals: lightly and to good effect. The middle school girls had more trouble. This may have been because their own notions of teaching were less mature, because they saw the student's role passive than did VT students, and/or because it was more difficult for them to imagine teaching in such a decontextualized situation.

One limitation of this work was that the learning task was confined to one factual task rather than a richer array of tasks including more complex inquiry-based learning. Another limitation is that the "teacher" was not motivated by the rich set of priorities and considerations that motivate a real teacher to intervene or not.

Strengths of the task include that it is in fact interesting for the participants, that there at least the two layers of learning (to recognize and name the characters), that it emphasizes the teacher's role, and that the recognition component is sufficiently complex to have produce a wide range of errors after two rounds.

Although these demonstrations are limited, we feel that there is enough evidence to go through the effort to incorporate *Look* functionality in a more contextualized teaching context. We do not expect *Look* to be used constantly, perhaps only twice or three times in a class section; however, we expect that it will disambiguate situations such as that reported in the initial paragraph of this paper that otherwise would not be clear.

An additional direction has to do with the of future IR beaming. We worked with IR in the NetCalc project and therefore in this one because it solves a raft of classroom management problems. When the teacher or the teacher's machine functions as a central server, any problems tend to involve the whole class and be disruptive. Point-to-point beaming allows localized control but participants with no need for the system to know who is working together. We have found it to be extremely useful and easy for small group interaction. However, it is unclear that IR will continue to prevail on inexpensive handheld machines, compared to radio-frequency (RF) communication. Thus, our research has to extend to include RF. With its nearly synchronous properties, teachers should have an easier time seeing activity in progress with RF. There will be no need for static snapshots. However, RF-based *Loo*king may still be time consuming and problematic because of the need for machine to know which other machine or machines to be *Look*ing at. RF alone may not suffice to make the teacher's assessment of the learning situation as automatic as with a desktop display.

CONCLUSION

One of the fundamental design goals of this project was to support the role of the teacher in learning situations as a "guide on the side" in relationship to handheld wireless computing. We investigated using Look functionality for weak guidance in classroom activities, in which the teacher could come to understand the intellectual state of small groups at work. The result of user experience with our prototype and a few triads with a non-Look control, gives preliminary indication that Look can be used to enhance classroom communication and understanding; however, the case is not closed, creating interesting design challenges in the social or technological realm or both.

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The Effects of Remote Gesturing on Distance Instruction

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Abstract. In this paper, we describe an experimental research study, investigating the impact of varying communication media on the quality of learning. Our study investigates remote instruction using an object assembly task. The between-subjects independent-measures study compared instruction via audio only, with instruction via a remote gesturing system. Measures included assembly speed and assembly accuracy and were recorded during instruction and post-instruction at 10min and 24hr intervals. Perceived Instructor presence and other interpersonal variables were assessed via questionnaire. Results showed that remote gesturing during instruction led to significantly faster self-assembly 24hrs post instruction ($t\ (13) = 1.73$, $p \leq 0.05$). Whilst the use of gesture reportedly reduces communicative rapport, we conclude that gesture-based remote instruction improves the overall efficiency of remote collaboration.

Keywords: expert, novice, remote gesturing, remote instruction, collaborative physical tasks

INTRODUCTION

Learning is often characterized in terms of the relationship between Instructor and Learner with the Instructor either passing on knowledge or creating an environment for the Learner that is rich for self-discovery (e.g. Vygotsky's zone of proximal development, Vygotsky, 1978; Bransford et al., 2000). During instruction the Instructor must be able to define the limits of understanding of the Learner, they must successfully pass on knowledge and they must be able to competently assess that the Learner has understood (Tharpe & Gallimore, 1988). All of this is an interactive process based on communication feedback loops. Indeed, Garfinkel (1967) and Sacks (1992) stress the social construction of meaning during dyadic interactions. Similarly, research within the CSCL community has highlighted the importance of dyadic communication for remote interactions, where the Instructor may not be co-present with the Learner. As Stahl (2002, 2004) indicates, CSCL communication takes place primarily though discourse with communication breakdowns being resolved through the process of the discourse. The work of Garfinkel (1967) and Sacks (1992) also stressed the ways in which interactive factors other than speech (such as non-verbal behaviour) also help to construct meaning.

One factor in particular, that is important for the extraction of meaning from an interaction is the expression of gesture (McNeill, 1992; Clark, 1996; Kendon, 1996). Indeed, research has demonstrated that the adequate expression of gesture can be critical for establishing conversational grounding (Fussell et al., 2004), especially in those elements of discourse, which have a strong spatial reference (Rauscher et al., 1996). Inherently without gesture representation in a remote interaction much of the discourse becomes an attempt to secure conversational grounding (Kraut et al., 1996), e.g. the talk becomes 'about the talk'.

In this paper we are particularly interested in the ways in which gesture can be supported in remote learning environments and examining the learning effects of remote gesturing techniques. Our interest is in tasks that have been characterized as 'remote help giving' (Tolmie et al., 2004) where one of the collaborators has the task knowledge and one of the collaborators manipulates the task artefacts. Kraut et al. (2003) state that such tasks:

> "…fall within a general class of 'mentoring' collaborative physical tasks, in which one person directly manipulates objects with the guidance of one or more other people, who frequently have greater expertise about the task." (p.16)

In these situations there is a clear asymmetry between the roles and requirements of the collaborators, and the task clearly resembles a learning or instruction experience. Typical examples of such tasks include remote expert medical assistance, supporting remotely located junior surgical teams or paramedics in the field, or situations in manufacturing, e.g. machine repair or plant maintenance incorporating expert guidance (see Fussell et al., 2004). Whilst an ideal instructional situation might involve co-locating instructor and learner, practical constraints may interfere, such as pressures on time or budget. Remote instruction may overcome such practical constraints.

However, the reduced availability of embodied behavior in remote instruction may seriously degrade the experience of the learner.

Research effort is therefore being expended in the design of technologies to support such remote instruction situations, with an emphasis being placed on the remote representation of non-verbal behaviour, most prominently gesturing (Kato et al., 1997). There are a variety of ways in which this can be achieved, different approaches including human proxy robots (GestureMan; Kuzuoka et al., 2000), direct video-based representations of hands (Agora; Kuzuoka et al., 1999) and video-based sketching (DOVE, Ou et al., 2003). However, when collaborators are not side-by-side they have different perspectives on the task depending on the medium of communication between the remote sites. As a result, they may approach the task with differing levels or types of knowledge. This mismatch of perspectives has been referred to as 'Fractured Ecologies' (Luff et al., 2003) and creates observable problems in collaboration. Each of the systems mentioned above displays this issue in varying degrees.

This paper describes initial experiments in overcoming this fracture in the ecologies of instruction by providing technical arrangements that provide remote gesturing support. We have developed a system with which to explore how a closer alignment between remote ecologies increases the presence of the remote collaborator in the task space. The aim is to understand whether such an increased alignment will give a more useful representation of non-verbal behaviour from instructor to learner. This paper begins by motivating the use of aligned gesture in providing mixed ecologies for remote instruction. We then discuss existing technologies for gesture support. We proceed by describing our system and experiments that investigate the use of remote gesturing. Finally, we discuss how the findings of our experiment support the use of aligned remote gesturing in conducting instruction.

The Emergence of Remote Gesture Technologies

Remote gesture systems emerged from early media space research where experimental studies (Ochsman & Chapanis, 1974; Daly-Jones et al., 1998; Kraut et al., 2003) indicated that merely linking spaces through audio-visual video links does not improve performance to the levels observed between side-by-side collaborators. The importance of gestures in face-to-face collaboration was stressed by Tang (1991) with later studies by Bekker observing that many hand activities in physical workspaces were gestures to express ideas (Bekker et al., 1995). These studies suggested that support for remote gesturing could improve cooperation beyond the capabilities of simple video links and motivated research into a number of remote gesture systems.

Two broad classes of gesture system have emerged. ***linked gesture systems*** directly represent remote gestures within the local environment while ***mediated gesture systems*** use an artificial representation of remote gestures. Linked gesture systems have emerged from efforts to study remote collaborative design work using video connections (Tang, 1991) and led to the development of several technologies such as VideoDraw (Tang & Minneman 1990), VideoWhiteboard (Tang & Minneman, 1990) and Clearboard (Ishii & Kobayashi, 1992). These systems exploit video projection techniques to support collaboration around the construction of shared 2-D artefacts such as drawings. Mediated gesture systems are more diverse. Early systems such as Commune (Bly & Minneman, 1990) used sketching to remotely gesture around shared digital artefacts and a range of systems have emerged that use a visible embodiment such as a telepointer to convey gestures (Gutwin & Penner, 2002). More recently mediated gesture systems have focused on how gestures may be manifest in the real world and support the physical manipulation of 3D objects.

Systems such as Drawing Over Video Environment (DOVE) (Ou et al., 2003) allow an Instructor's remote gestures to be fed to a local Worker. Gestural sketches are overlaid on a video representation of the working area presented via a monitor in the local task space. The work of Kuzuoka et al.. in the development of GestureCam, GestureCar and GestureMan (Kuzuoka et al., 2000) has focused on directly embedding remote gestures into a working environment through the use of a laser pointer. However, the laser pointer obviously has a lower bandwidth for the expression of gestural information than the direct presentation of hand gestures or sketches.

Realizing remote gesture systems has not been without its difficulties. A particular concern has been the extent to which 'Fractured Ecologies' (Luff et al., 2003) have emerged where the remote and the local ecologies are too distinct, creating a barrier to understanding and conversational grounding. This is most prominent in the mediated gesture systems concerned with collaborative physical tasks. For example, within the GestureMan system local workers could not assess the situational awareness of the remote instructors as they were not aware of what the experts could see (Luff et al., 2003). While in the DOVE system (Ou et al., 2003) the local worker needs to extrapolate from the overlaid sketched information from the remote helper presented on a separate video monitor to their own local ecology.

Gestures in Instruction

As researchers have developed these various technologies to support remote gesturing it has become necessary to find ways of isolating improvements in the quality of interaction. One common methodology used to demonstrate the success of the technology has been to provide evidence for immediate performance benefits. Experiments are constructed which demonstrate whether a particular remote gesturing device improves performance speed in a standardized collaborative physical task (e.g. Fussell et al., 2004). However, the use of such metrics circumvents the inspection of particular applications. The dynamics of situations such as those where an instructor guides a learner through some physical process in the hope of successfully imparting knowledge, require further investigation. Specifically, experimental approaches to understanding remote gesturing systems have failed to consider the impact of such devices on learning. By focusing solely on the immediate task performance benefits rather than any assessment of longer-term knowledge development the research literature rarely discusses whether the newly developed remote gesturing techniques actually provide benefits for remote learning, which cannot be replicated by current methods of remote help giving (such as telephones or videoconferencing).

We would argue that successful learning-oriented interaction depends on the access for both instructor and learner. The use of a system to provide a remote worker access to an instructor's non-verbal behaviour (such as gesture) should improve the quality of learning that is achieved during the interaction. Remote gesture should facilitate conversational grounding (Fussell et al., 2004) meaning that less time in a time-limited interaction is given over to 'talking about the talk' and more time can be spent discussing salient learning features. Whilst there might be something to be gained from extending discussion during a learning interaction, there are often clear economic constraints for this class of remote instruction situations, which necessitate that learning should be expedited. We would anticipate that the facilitation of gesture, which normally occurs as either a component of utterances in alternation with speech or in conjunction with speech (Kendon, 1996) should improve understanding in collaborative physical tasks, especially given that discourse must relate to spatial concepts (Rauscher et al., 1996). Equally, in situations where a learner attempts to perform the task at a later time on his or her own, they might be able to recognize hand shapes and gestures that they are performing, which would prompt instruction recognition. This hypothesis is reinforced in experiences with the use of previous remote gesturing systems (Kirk et al., 2004) which have shown evidence that users will map their hand movements onto the hand movements of instructors demonstrating physical manipulations of task artefacts or indicating locations of interest.

Nonetheless, there exists a counter-argument that might indicate that providing a representation of gesture for remote instruction could impair learning. If one were to consider the 'Agentic' personality role described by Milgram (1974) or indeed theories of automatic processing within work on attention (Shiffrin & Schneider, 1977) it could be argued that with increased physical presence during remote instruction and less interactive discourse, learners might simply perform actions as they are instructed without considering in depth the nature of the task they are performing.

Our technological arrangement

We wish to explore gesturing in remote help giving situations where the technologies seek to minimize the differences between the ecologies of the local Worker and the remote Helper. To effectively embed remote gestures in the local ecology and provide a rich representation of hand gestures we exploit direct video-projection. Figure 1 illustrates the general technological arrangement.

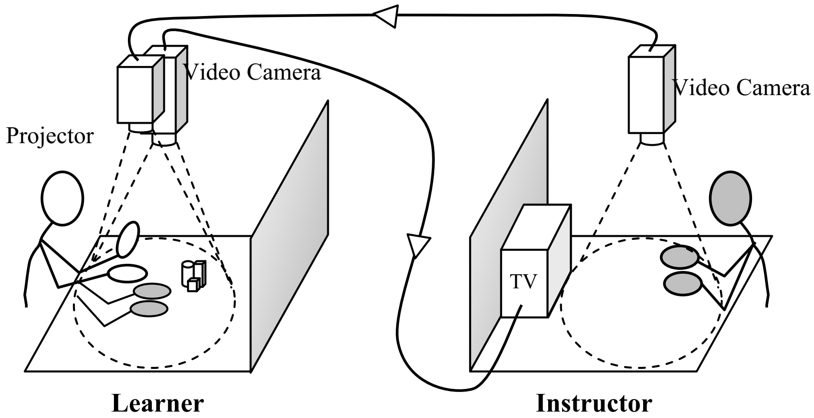


Figure 1. Schematic of Gesture Projection System

A video camera was used to capture images of one collaborator's hands (***the Instructor***); these gestures were then projected onto the desk of the other collaborator (***the Learner***), who had the task artefacts on their desk. These remote gestures were therefore captured and posited directly into a remote ecology, creating a mixed reality surface at the level of the task space. The resulting images played out at the mixed reality surface were also captured by a second video camera and passed back to a TV monitor situated on the desk of the Instructor. This allowed the Instructor to see artefacts in the task space, to see the Learner's progress in assembly and to see their associated gestures and also to guide their own gestures in relation to the shared artefacts. This arrangement exploits two key features to help align the remote and local ecologies:

- *The gestural output from the remote situations is directly embedded in the local environmen*t. Remote gestures are directly projected into the local space. This arrangement extends the approach suggested by systems such as DOVE (Ou et al., 2003) where remote gestures are made available on a separate display.
- *The gestures are un-mediated.* We directly project gestures captured form video camera allowing us to preserve the richness of expression of the remote user's gestures and reduce the costs of interpretation.

The asymmetric nature of the Learner-Instructor dynamic is also reflected in the physical arrangement of the technology. Essentially, our aim here is to encourage the remote Instructor to share the same ecological arrangement as the local Learner. In order to do this we made two design choices in assembling our technologies:

- *The remote Instructor shares the same orientation to the task space as the local Learner* with their gestures projected on top of the local Learner's rather than arranged face to face.
- *The remote Instructor views their gestures on the remote work surface* alongside the artefacts and the gesture of the remote user rather than projecting the work surface into the Instructor's environment.

This arrangement is in contrast to the use of video projections within Agora (Kuzuoka et al., 1999) and VideoArms (Tang et al., 2004), which adopt a face-to-face (or side-by-side) orientation for remote and local participants and more symmetric projections that reflect the more equal collaborative arrangement they seek to support.

STUDYING THE TECHNOLOGY

We have developed the technological arrangement described in the previous section in order to assess its value in supporting remote interactions for collaborative physical tasks involving a strong instructional emphasis. Rather than studying performance effects, therefore, we developed a method of understanding the role of instruction itself in such scenarios. Given the paucity of literature available on learning effects in remote instruction, we chose to study post-instruction performance by asking learners to complete a task on their own after being instructed. Testing post-instruction effects should eliminate the possibility that learners are blindly following instructions without retaining task knowledge in their own right.

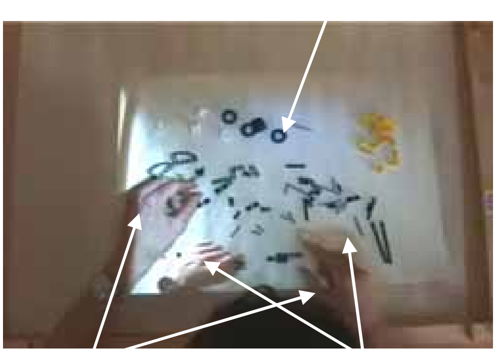
Design

The study was conducted using a between-subjects independent-measures design. We employed one independent variable, communication condition, which consisted of two levels, voice-only and voice-plus-gesture. One participant was trained in the task to allow them to provide all instruction to participants during the task. Each of the learners experienced only one form of communication condition. Presentation of the two communication conditions was counterbalanced across participants, to avoid the instructor developing a learning bias by becoming more familiar with one instruction method over the other. The dependent variables included assembly speed and assembly accuracy measured during instruction and post-instruction at 10 minute and 24 hour intervals, following a delayed post-test design. A further questionnaire obtained data on perceived instructor presence and interpersonal variables, which also acted as a distraction task during the 10-minute interval after the instruction period.

Equipment

The gesture projection apparatus (see figure 1 for schematic, figure 2 for illustration of system in use) consisted of two bespoke wooden frames, positioned on a standard non-adjustable working desk. Frame 1 held a digital video camera attached to a boundary microphone and an LCD projector. Frame 2 held a digital video camera only, and incorporated a 14" Television. A Lego™ kit (model no. 8441) was used for the assembly task. Video recordings of the experiment were taken from the video camera on Frame 1 (so as to cover in-depth the mixed reality surface) and an additional video camera was used to give a contextual perspective that recorded participant's behaviour during the post-instruction learning assessment.

Parts for assembly



Local Learner Hands Remote Instructor Hands

Figure 2. Gesture Projection System in use

Procedure

The study examined the impact on learning of using a projected gesture system in remote instruction situations. In these situations the learner has physical artefacts to manipulate. The instructor has a video view of the task space and can communicate normally through audio channels. This participant was not told the hypotheses of the study.

During the experiment, participants were randomly assigned to one of two groups (either voice only or voice-plus-gesture). Each participant was then remotely instructed in how to assemble the final stages of a Lego™ forklift truck model. The majority of the model had already been completed so that complete assembly was achievable within the time limit and consisted of a recognizable end goal state. One group of participants experienced the instructions with the aid of projected gestures; the other group experienced the instructions in audio only. Prior to instruction, participants were made aware that they would be required to assemble the model themselves after instruction. The instruction in object assembly lasted until the model was completed (up to a total of 10 minutes). After assembling the model, participants were given a distraction task for 10 minutes, which included the completion of questionnaire on the experiment and then a large number of simple mathematical problems. Participants were then given a further 10 minutes to independently try and complete as much of the object assembly as they could from the same starting point. This attempt at self-assembly was then repeated approximately 24 hours later. All attempts at self-assembly were video-recorded, as was all instruction, using recordings from the video cameras integral to the technological set-up.

The time required to complete instruction in how to assemble the model was recorded. Measures of time taken were then also recorded as participants assembled the model for themselves after 10 minute and 24 hour intervals. The numbers of mistakes made on each completed model were also calculated (on a simple scoring method with points derived for the correct piece of Lego™ being used in the correct place and in the correct alignment). The change in time taken to complete the model from instruction to 1st self-assembly and then to 2nd self-assembly was also calculated. Responses to the questionnaire items were also analysed.

Participants

A total of 18 participants took part in the study, 14 females and 4 males. Participants' ages ranged from 19-37 years (mean 23.5, st. dev. 5.16). They were primarily undergraduate students. Participants were paid a small fee for taking part in the study. One participant (a female student, aged 26) acted as the instructor for all trials, and was paid a larger fee for participation. The instructor had prior experience and training in using the gesture projection apparatus, and had received four hours training in constructing the model prior to the experimental trials. One female was excluded from the data analysis as her instruction phase was severely interrupted. Sixteen participants returned for the second self-assembly (with 2 dropping out), returning an average of 23hrs 54mins after the start of their instruction period.

RESULTS

Table 1 details the average Time Taken to complete the model and the number of mistakes made in each of the three phases of the study, grouped by instruction method. The results indicate that the amount of time participants took to self-assemble the model on the first attempt was longer than their original instruction time.

However, after 24 hours, learning had apparently consolidated and time taken to complete the model had dropped dramatically. The number of mistakes made followed a similar pattern. Differences in performance between the three phases of the study are statistically significant for both Time Taken (one-way repeated-measures ANOVA ($F(2,15) = 8.88$, $p \leq 0.001$)) and number of Mistakes (one-way repeated-measures ANOVA ($F(2,15) = 9.25$, $p \leq 0.001$)).

	Instruction		*1st Self Assembly*		*2nd Self Assembly*	
	Time Taken	Mistakes	Time Taken	Mistakes	Time Taken	Mistakes
Voice only	358	0	471	5	357	3
Voice plus Gesture	320	0	441	2	229	2
Average	340	0	457	3	297	2

Table 1. Time taken (in seconds) and number of Mistakes made during model construction in three phases, Instruction, 1st Self Assembly (after 10mins) and 2nd Self Assembly (after 24hrs), by Instruction communication condition. (N=18)

The Time Taken to complete the assembly can be seen in Figure 3 and the pattern of mistakes over the experimental phases is shown in Figure 4.

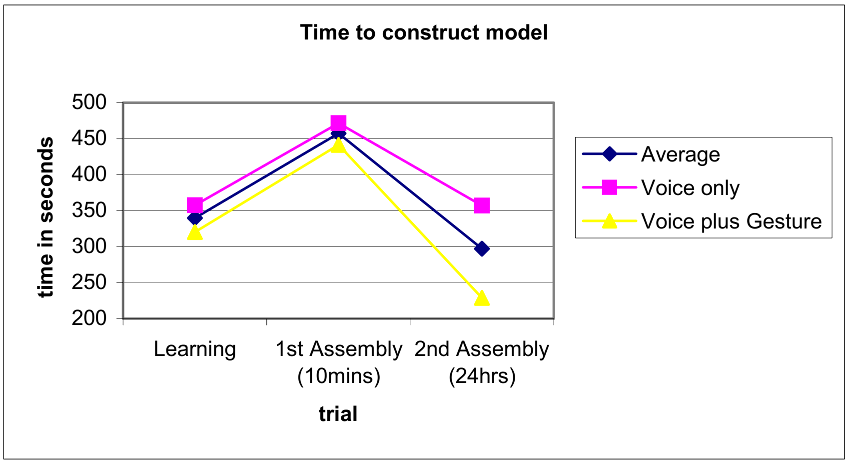


Figure 3. Time to complete model in each of three phases

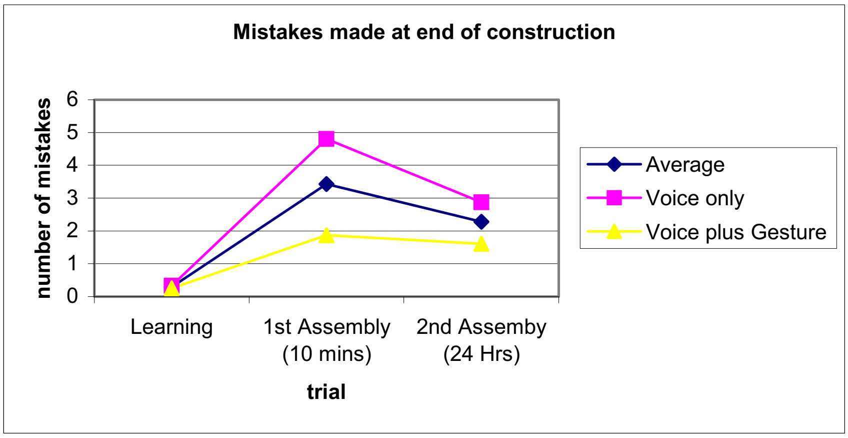


Figure 4. The numbers of mistakes made in each experimental phase

Analysis of the number of mistakes made in each condition showed no significant differences during instruction or during self-assembly 24 hours post-instruction. The number of mistakes made during self-assembly 10 minutes post-instruction did show a strong trend indicating more mistakes in the voice only instruction condition but the difference was only approaching significance ($p \leq 0.06$). An analysis was also carried out on the performance times in each of the three phases. Despite the trends shown there was only one significant difference found between the Instruction communication conditions. This was for the second self-assembly trial.

After 24 hours it appeared that those participants who were instructed with the aid of remote gesturing were assembling their models significantly faster than those who had not experienced remote gesturing ($t(13)=1.73$, $p\leq0.05$). Intriguingly, as demonstrated in Figure 3, the data also suggests that whilst those who were instructed by voice alone had a self assembly performance speed that returned to the level of their performance during instruction those who were instructed with voice plus remote gesturing had a self assembly performance level on the second self assembly that was in fact better than their performance during instruction. The effect size for this difference was 0.89 using Cohen's *d*.

A further analysis was therefore conducted to consider the change in performance speed after initial instruction. This demonstrated that after initial instruction assembly times went up relatively equally regardless of instruction method, and after 24 hours assembly times dropped (see table 2).

	After 10mins	*After 24hrs*
Voice only	114	-98
Voice plus Gesture	121	-215
Group Average	117	-153

Table 2. Change in time taken to complete model after 10 minutes and then after 24 hours by Instruction communication condition. (N=18)

The drop in assembly times after 24 hours appears to be most marked for those participants who were instructed using remote gesture, their assembly times dropping on average more than twice that of those instructed by voice alone. Those who experienced remote gesture instruction had significantly improved performance over the other group ($t(13)=1.83$, $p\leq0.045$). The effect size for this difference was 0.95 using Cohen's *d*. The inclusion of remote gesturing during instruction therefore appears to produce better performance amongst participants in later attempts at self-assembly. We conclude that remote gesturing during instruction has improved task learning.

Improved performance with a poorer perception of involvement

The study was complemented by a questionnaire administered to the participants whilst they were being distracted prior to the first attempt at self-assembly. The questionnaire consisted of 12 analogue rating scales. The scales used disagree-agree anchor points, and were used to provide a percentage value of agreement with each given statement. Data was computed by measuring the distance from the lower end of the (100mm) scale to the mark placed along the line by the participant. The statements centred on the participants' perceptions of the instructor and their interaction, gauging how much the learner liked / trusted / understood the instructor, how well they thought they did on the task / would be able to do it in future and how much the technology impacted on their ability to communicate with the instructor.

Two statements (highlighted in figure 6) were found to significantly differ by instruction communication group. Those participants who had experienced instruction utilizing remote gesture actually rated the instructor as slightly less likeable ($t(16)=-2.08$, $p\leq0.05$) and simultaneously were actually more likely to agree with the statement "I felt like I just did what I was told to do" ($t(16)=2.65$, $p\leq 0.02$), which demonstrates a perceived lack of involvement with the task. Both of these suggest a particular orientation between the learner and the instructor with the learner less involved in determining the manipulations being undertaken and less of a rapport emerging during the instruction.

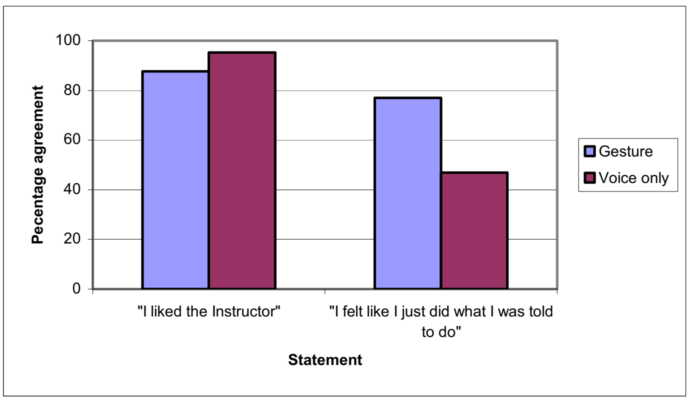


Figure 6. Responses to two statements by Instruction communication group

In summary the results have demonstrated that immediately after instruction there is a refractory period wherein performance may be impaired (with potentially larger numbers of mistakes made by those instructed via voice only methods). After a period of consolidation, however, knowledge has been retained and performance in self-completion of the task improves (both in performance time and number of mistakes made). For remote instruction in the performance of physical tasks we have shown that learning can be improved through the use of a remote gesturing device. Using this method of instruction over audio-only methods significantly improves subsequent task performance. The results have also indicated that whilst performance is improved, learners may have inferior perceptions of the instructor, regarding them as more impersonal, and they feel subsequently less involved in the task as they are learning.

DISCUSSION

The aim of this study was to investigate the impact of using a remote gesturing device on the quality of learning achieved during remote instruction. In line with this aim the study has demonstrated that the use of such a device during instruction in a physical task leads to significantly improved speeds of self-performance of the task 24 hours post-instruction. Intriguingly, however, the study has also demonstrated that the relationship between the instructor and the learner is affected by the use of the technology, slightly impairing the ability of the instructor to develop a rapport with the learner. However, this effect on the relationship does not have a negative impact on the quality of the learning, as performance is improved when remote gesturing is used during instruction.

One way in which we might seek to understand these results would be to consider Hutchins' (1995) discussions of Distributed Cognition and descriptions of information representation passing and propagating between individuals and their task artefacts. Hutchins' would suggest that in group situations it is only through this flow of information that complex tasks can be achieved. We would argue that information is easier and quicker to access if the changes in representative state have been kept to a minimum and the translational overhead introduced by any mediating technology is kept to a minimum. We would suggest that our two conditions reflect different levels of translational overhead.

The overhead of "translating" representations

In our voice only case, the instructor can see items in the task space but not point. This means that then they need to translate their visuo-spatial instructions into a verbal code which must be transmitted to the learner and then be decoded introducing a significant overhead. This decoding process causes Luff et al.'s (2003) 'fractured ecologies' to become evident, as any mismatch between the perspectives on the task of the instructor and the learner will render the process of decoding talk and then resituating visuo-spatial information within the learner's ecology much harder.

Alternatively, a particularly close alignment of remote and local ecologies such as that used in our experiment provides direct visuo-spatial reference intact. The instructor can make gestural references, which are aligned with the learner's visual perspective on the task. Therefore, references can be kept in a spatial medium when presented remotely. This reduction in the amount of processing required for the translation of information reduces the effort required establishing conversational grounding (Fussell et al., 2004). Such considerations are reinforced by the arguments that meaning in a dyadic interaction is derived in part from awareness of interpersonal behaviours such as gesture (Garfinkel, 1967; McNeil, 1992; Clark, 1996).

Improved effects over time

Our results found no significant difference in times taken for initial instruction between the voice-only and voice-plus-gesture groups. There is a possibility that the similar times for instruction are derived from different types of interaction. It may be that in the gesture condition more time was spent on salient features of the task and less time was spent 'talking about the talk'. Nonetheless, analysis of our data by studying the composition of the talk used in the two conditions would be required to substantiate this claim, and such claims have already been made with regard to the impact of gestural information during instruction (Clark & Krych 2004). Relying on the questionnaire data, results suggest that in the remote gesture condition learners felt more directed and less involved in the task. Perhaps the continual resolution of difficulties in talk in the voice-only condition allows greater immediate reflection on the necessary features of conducting the task. However, the answer to this problem probably lies in a consideration of the nature of recall and recognition memories (Baddeley, 1990). It is possible that the improved performance after 24 hours for those in the voice-plus-gesture condition derives from the ability of the task to trigger memories of the physical and embodied demonstration of task performance available with the gesture instruction. Despite Kendon's (1996) comments that gestures are largely unconscious and most gesturers would be hard pressed to recall exact gestures that they had used in prior moments, there is evidence that gestures do implicitly convey information (see Kendon, 1994, for a review), enriching the learning environment. When the learners have been instructed with the aid of remote gesturing it could be argued that they are receiving visual cueing of their actions as they manipulate the model. This contextual cueing should promote recognition memory (Chun & Jiang, 1998) of the instructions. Certainly we might appropriate distributed cognition to support this idea, given that performance could be enhanced if the cognitive processing of an instruction is performed inherently by its representation.

We have not collected data that might be used to assess the differences in level of understanding of the task between the two groups, so no conclusions can be drawn as to whether those instructed via voice-only better understood the task. However, given the simplicity of the task in this situation, there is very limited capacity for developing a deep understanding and indeed this factor would vary with tasks of an increased complexity. This raises the issue of whether a technology should be designed to facilitate the making of mistakes for learning. Such a complex domain requires many task-dependent metrics to understand how the technology supports the learning involved.

CONCLUSIONS AND FUTURE WORK

In this paper we have explored the use of remote gesturing technologies to support the situated learning involved in remote help giving. We have shown that the use of gesture for remote instruction significantly improves subsequent task performance in the performance of physical tasks over audio-only methods. We have also provided evidence that, whilst performance is improved, learners may actually have poorer perception of the instructor, regarding them as more impersonal. This can lead to a perception of less involvement in the instructed task.

There are limitations to the scope of this study. Firstly we have demonstrated only a simple assembly task, and such results need to be compared with instruction in more complex physical tasks. Equally only one instructor was used and as such gesturing behavior itself was idiosyncratic. Further work is therefore required in understanding the capacity for various instructors to adequately use a remote gesture tool. One final limitation that is of importance is that learners were made aware that they would have to perform the task on their own post-instruction. This may have influenced how well information was retained and the results could vary if subjects were not aware of a later need for the knowledge. This is an especially important point to consider given questionnaire results that indicate participants felt more directed and therefore less engaged in the gesture instruction condition. Such an effect might produce poorer performance in informal *ad hoc* learning situations.

Conversely, we have also provided an indication that tools and technologies for remote instruction may prove beneficial given adequate consideration of the alignments of local and remote ecologies. Systems designers may benefit from our study in understanding how remote instruction systems may be optimized for instruction, but such work requires further results to fully understand the relationships between remote instruction, technological arrangement and learning benefits. Finally, we plan to analyse and consider the basic structure of the remote gesturing apparatus, i.e. the representations of gesture used (unmediated views of the instructor's hands versus video-sketching) and the location of the gestural output relative to the task space (embedded, as in this experiment versus externalized with a video window). These analyses will emphasise the features of our study that we have demonstrated to be of importance for supporting remote instruction. The impact on learning of mixed ecologies both during and after remote instruction must be considered.

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Collaborative Learning through Augmented Reality Role Playing

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Abstract. This research investigates the potential of Augmented Reality (AR) technologies, specifically handheld computers, to create an emotionally compelling, rich context for collaborative learning. Building on work in collaborative learning, we sought to design games requiring positive interdependence, promotive interaction, individual accountability, interpersonal and small group skills, and group processing. While the collaboration within groups was strong and successful in the first generation AR games, the collaboration between groups was limited or non-existent. Several new game play elements added to a new engine created a more dynamic game play experience. These features included time dependence, cascading events and distinct player roles. In subsequent iterations of AR games, we have found these new features to be effective at fostering collaboration, which in turn scaffolds a more authentic investigation process

Keywords: Handhelds, games, simulations, role play, PDA

INTRODUCTION

Handheld computers make possible new kinds of field investigations where learners collect data, access authentic tools and resources, and participate in collaborative learning practices while in the field (Roschelle & Pea, 2002; Soloway et al., 2001). Whereas traditional desktop VR applications or 3D gaming technologies such as MUVEs (e.g. Dede et al. 2004) burden the developer and computer with representing 3D, augmented realities exploit the "3D" characteristics of the real world, and instead provide users with layers of data that augment their experience of reality. As a result, simulations are untethered from the desktop and learners can physically and actively participate in technology-enhanced investigations, location-based games, or participatory simulations. Because players are free to move throughout the world, novel opportunities exist for learners to interact with the physical environment, literally reading the landscape as they conduct environmental investigations or historical studies. This also frees up students to communicate and collaborate in natural ways. Students can talk and communicate with body language as they do everyday, rather than investing effort in developing communication skills relevant only within a purely virtual world. In sum, by integrating more of the real world, handhelds can create experiences that differ in significant ways from more traditional desktop computer based environments.

Leveraging design techniques from role playing games (c.f. Gee, 2003), we believe that opportunities exist for immersive gaming environments to recruit players into assuming new identities as environmental investigators, scientists, and environmental activists, thereby encouraging them to adopt epistemic frames that might be ideal preparation for future learning (c.f. Schwartz & Bransford, 1999; Shaffer, 2004). This research is investigating the potential of Augmented Reality (AR) technologies to create this kind of emotionally compelling, rich context. AR devices superimpose a virtual overlay of data and experiences onto a real world context. Early work on AR (Klopfer et al. 2002, Klopfer & Squire 2003, Falk, et al. 2001; Waltz 2002) indicates that AR simulations can be designed not only to support learning disciplinary content knowledge, but also to provide opportunities for students to develop critical 21st century IT skills including collaboration and information sharing, managing uncertainty, and analyzing complex systems (c.f. Beck & Wade, 2004). While initial trials of this technology are broadly discussed elsewhere (c.f. authors, in press), this study focuses on the design for social interactivity (or sociability), and how this is designed into the software and emerges during game play. When designed correctly, they can present authentic problems, give students access to investigative tools, and structure experiences to foster collaboration. Using a design narrative technique (c.f. Hoadley, 2002), this study seeks to provide an account of a research project over several design iterations that might illuminate the tensions behind designing for collaboration. Building on work in collaborative learning (e.g. Johnson, et al.

1994), we sought to design challenges (or games) requiring positive interdependence, promotive interaction, individual accountability, interpersonal and small group skills, and group processing (See Table 1)

Positive interdependence	Group members perceive that they are linked with each other so that one cannot succeed unless everyone succeeds.
Promotive interaction	Students promote each other's success by helping, assisting, supporting, encouraging, and praising each other's efforts to learn.
Individual accountability	Each individual student's performance is assessed and the results are given back to the group and the individual.
Interpersonal and small group skills	Interpersonal and small-group skills required to function as part of a team (teamwork)
Group processing	Group members discuss how well they are achieving their goals and maintaining effective working relationships

Figure 1. A screen shot of a handheld AR game (left) and 2 players conducting an AR investigation (right).

GENERATION 1 – ENVIRONMENTAL DETECTIVES

Our first AR simulation, Environmental Detectives (ED) (Klopfer et al. 2002), engaged high school and university students in a real world environmental consulting scenario constructed to immerse players in the practices of environmental engineers, giving them a “virtual practicum” experience, similar to working on an environmental research team. Students role play as environmental scientists investigating a rash of health concerns on site linked to the release of toxins in the water supply, a scenario loosely based on actual historic situations. The main focus of the game was on planning an effective investigation that balanced quantitative and qualitative data.

Working in teams of two or three, players attempt to identify the contaminant, chart its path through the environment, and devise possible plans for remediation if necessary. As students physically move about campus, their handheld devices respond to their location and show their current location on a bird’s eye view map, allowing them to collect simulated field data from the water and soil, interview virtual characters, and perform desktop research using mini-webs of data. At the end of the exercise, teams compile their data using peer-to-peer communication and synthesize their findings into case reports.

The problem space of ED is quite vast. By design, no one player can obtain all of the requisite information in the allotted time, and teams had to work with each other to collect data and come up with solutions. Each team had one Pocket PC, one walkie-talkie, a printed map and a notepad. Teams typically assign one player to the Pocket PC/map, and another player as notetaker and/or communicator. This promoted strong collaboration within teams – forcing players to work together effectively for navigation and planning. In most cases players were not specifically instructed to either collaborate or compete with the other teams in the game, but to use their judgment in order to devise the best solution and provide the strongest evidence. By creating this large physical space, which can easily be geographically subdivided, we were most strongly emphasizing positive interdependence. It should be noted that in ED, there is no “role” differentiation among players and, since all players are using the same software, they can potentially access the same information at the same time. Table 2 (below) depicts the components of Environmental Detectives designed to promote collaboration.

Promotive interaction	Moving in physical space, students working collaboratively can cover more ground and share information by looking at each other's screens. One group’s information is often evaluated on the spot by other groups.
Individual accountability	Each pair of students is responsible for presenting their case to the class at the end of the experience. This is often supplemented by written arguments.
Interpersonal and small group skills	Groups of students communicated via walkie-talkie to share information or pool data.

Group processing	A classroom/lab space provides a shared location where students could plan next steps, assemble evidence and ultimately present their case to the class.

Nearly a dozen classes have run through ED. Here we examine collaboration within and across teams, one an environmental science class from a suburban high school, and the other a chemistry class from a private all-girls high school, both in the Boston metropolitan area. Through these runs we have found that collaboration within the teams was quite strong. Both groups of students collected interviews and used sampling , though how much weight they gave to these qualitative (interviews) and quantitative (sampling) activities varied greatly.

Suburban High School. Looking at one team of three students towards the end of their investigation, they start to evaluate what they know, and they grow concerned that they do not have enough information to make a compelling case about the toxin. We pick up the discussion as they decide what to do next:

Louis: My socks are so wet.
Camera: We should head back soon.
Gina: Yeah, it is 12:50.
Louis: How far away is the thing [place they should return to]?
Gina: Where do we have to go again?
Stacey: Alan Morgan center? That is…
Louis: [Looking around]. Not around here.
Stacey: Right here [points at paper map].
Stacey: How are we supposed to make recommendations?
Gina: I don't know.
Louis: Just read off of the information that we got.
Gina: I thought we could dilly-dally but we actually did work.
Louis: For once.

One of the defining characteristics of the experience was a constant shifting of goals. Students were expected to manage their problem solving, reframe the problem as new information became available, and in short "work" toward finding a solution. Much of this work, however, emanated from an "acquisition" metaphor of knowledge. Perhaps influenced by the field trip nature of the experience, some students thought the goal was to acquire as much information as possible and then develop the right answer. Here, late in the experience, they begin to understand that developing an answer requires negotiating and synthesizing information. Although this group shared a lot of information and fluidly navigated multiple information spaces, much of their collaboration centered around game mechanics, and less around collaborating to work through scientific dilemmas.

Evidence of collaboration between teams of students is sparser. During this run, several groups tended to frame the activity as akin to a scavenger hunt, with little consideration as to the significance of the information contained within each of these interviews.

Private Girls' School. Another class with previous experience in collaborative problem solving divided the problem space and worked together to efficiently solve the problem. The facilitator began by asking students what they knew, what they needed to know, and asked them to make a plan. The groups went out and collected data, and, mid-game, decided to pool resources and see what they had learned so far.

Two girls stand at the board and add to the list of facts already started earlier in class. A map is passed around the room, and students add where they found their toxins. To those familiar with knowledge building communities (Scardamalia & Bereiter, 1991) or jigsawing (Brown & Campione, 1996), the scene was quite familiar. Each student was adding what she knew toward building a more holistic view of the problem. What was particularly noteworthy about this session is the way that the facilitator quickly receded into the background. While she drove much of the initial conversation, students quickly took ownership of the problem and coordinating the discussion. For evidence typical of this, one student, Miranda interrupted the conversation:

Miranda: Before we go back out, can we go through the names of all the interviews and make sure that everyone's hit one at least?

We highlight this case not only to show how the task, designed to be unsolvable by any one person, *could* elicit coordinated problem solving actions, but also to show how the game activity is not solely a property of the software or design, but an interaction between the software design and the existing classroom culture.

GENERATION 2 – CHARLES RIVER CITY AND MAD CITY MURDER

While the collaboration *within* groups was strong and successful in the first generation AR games, the collaboration *between* groups was limited or non-existent, except in the last case, which showed that promoting collaboration at a larger scale requires providing additional scaffolding for collaborative learning. In order to promote greater collaboration between the teams, the core engine for our AR games was redesigned. From this redesigned engine two new games were created – Charles River City (CRC), which combines environmental science and epidemiology to create a large scale investigation, and Mad City Murder (MCM) which uses the

ED premise to create a mystery investigation. These games tap new features that were introduced into this engine including time dependence, cascading events and distinct player roles. The time dependence, which made the game change over time, and cascading events, which allow events to trigger other events, were added to provide a richer experience. Distinct roles were added to promote greater collaborative learning between teams.

Distinct roles added several key elements. First, players receive different information from virtual characters depending on what role they are playing. For example, a virtual character who is feeling sick might give a player in the role of "nurse" different information than she would give to the "detective". Second, roles have different data collection capabilities allowing them to collect unique types of samples or access unique kinds of data. For example, an environmental scientist might have access to water sampling equipment, whereas a medical doctor might be able to access medical records or get vital signs from virtual characters. Finally, since roles can access different information, players can use infrared beaming to exchange information between players. For example in CRC, a character reveals information to the "detective" about a student who has fallen ill. The "detective" must then beam that information to the "nurse", so that the "nurse" can interview the player and examine the specific symptoms and what might be causing them. Reconsidering the criteria for promoting collaborative learning, we see how these new game play elements have enhanced the potential for larger scale collaborative learning.

Positive interdependence	Each team's information is explicitly described to them as only a small piece of the puzzle, and they need information from other roles to solve the problem. This sharing is facilitated by the infrared beaming of information.
Promotive interaction	Students encourage players in the other roles to go out and get information that they know they need but cannot get themselves.
Individual accountability	Each role has access to unique information, necessary to solve the problem. Players know which role has access to the information that they need.
Interpersonal and small group skills	Sharing of information across teams via the infrared beaming becomes a point of instruction on how to share information and collaborate across teams.
Group processing	Groups could "divide and conquer" – with roles dispersing to find information and regrouping to exchange information at planned times or ad hoc, or move around in multi-role groups. Both strategies require getting together and planning how to move forward.

In subsequent iterations of AR games, we have found these new features to be effective at fostering collaboration, which in turn scaffolds a more authentic investigation process. The fact that sharing information could reveal new things encouraged frequent digital exchanges, which were accompanied by pertinent discussions of game progress. Here is a typical exchange of middle school students from an urban school in the Boston metropolitan area playing CRC. In this particular version, there are three roles – a doctor who can take people's vital signs and symptoms, an environmental scientist who can take samples from the water and air, and a department of public health expert who has access to hospital records and epidemiological data.

Manny: I got a document that says that says West Nile Virus has the most serious effects on people over 50.

Jane: So … the doctor might be the one that wants to talk to Salvadore [previously identified older patient] since he can get his health information.

The doctor goes to the location where Salvadore is and takes physical exam. A player in another role (Department of Public Health official – DPH) also goes along.

Sal [Doctor]: I was right! He has all of the symptoms of WNV [West Nile Virus].

Tricia [DPH]: [Radios to whole group via walkie talkie] I found Salvadore!

Sal: [Via walkie talkie] He has all the symptoms that he carries for WNV.

This collaboration between groups continues on into the classroom where they are making their recommendations on what to do about the problem. Each one of them contributes information that they got on the topic specific to their role (Environmental Scientist – Env).

Dave [DPH]: I found that West Nile Virus can make you really sick.

Tricia [Env]: Mosquitoes are all over the world so it is dangerous.

Manny [Env]: Not right now. Since it is fall there aren't many mosquitoes out. Only in spring and summer.

Jose [DPH]: Julia [a character] said that an elderly man complained of swarms of mosquitoes.

Kim [Doctor]: We found the old man [Salvadore] that complained of symptoms that could be WNV.

Dave [DPH]: There might be enough mosquitoes where it could still be a problem.

Manny [Env]: So get rid of the ones that are there.

Dave [DPH]: Get rid of all of the water that is standing around like in old tires.

As seen in the above dialog, the different roles have different perspectives and different pieces of the puzzle. This encourages them to collaborate, which progresses into other forms of collaboration and discussion as they attempt to solve the problem at hand.

FUTURE DIRECTIONS

One of the key design considerations for the different roles within the AR games is how much overlap there should be between the roles. Too much overlap between the roles will remove the positive interdependence and individual accountability that encourage collaboration. However, too little overlap does not give the students enough common ground to discuss the problem space. We have found that when students access the same information, it serves as a promotive interaction – reinforcing students that they have done well. It also gives them a point around which they can begin discussion. They start piecing the puzzle together around the common pieces and then work towards their own unique contributions. As in the CRC example, all of the students learned that West Nile Virus was a serious mosquito borne disease, but only certain roles were privy to the seasonality, the current levels, or the symptoms. In our next phases we will study how increasing and decreasing overlap can affect learning outcomes, and how role interdependence relates to both subject matter and student experience.

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Mystery at the Museum – A Collaborative Game for Museum Education

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Abstract. Through an iterative design process involving museum educators, learning scientists and technologists, and drawing upon our previous experiences in handheld game design and a growing body of knowledge on learning through gaming, we designed an interactive mystery game called Mystery at the Museum (the High Tech Whodunnit), which was designed for synchronous play of groups of parents and children over a two to three hour period. The primary design goals were to engage visitors more deeply in the museum, engage visitors more broadly across museum exhibits, and encourage collaboration between visitors. The feedback from the participants suggested that the combination of depth and breadth was engaging and effective in encouraging them to think about the museum's exhibits. The roles that were an integral part of the game turned out to be extremely effective in engaging pairs of participants with one another. Feedback from parents was quite positive in terms of how they felt it engaged them and their children. These results suggest that further explorations of technology-based museum experiences of this type are wholly appropriate.

Keywords: Handhelds, games, simulations, role play, PDA, museum, wireless

BACKGROUND – GUIDED TOURS AND HANDHELDS IN MUSEUMS

It is well known that museums have sought ways to engage visitors both more deeply and broadly in museum resources. Technology has enabled museums to explore new ways to provide visitors with richer experiences without necessarily producing additional physical exhibits. Many museums have employed audio tours, utilizing customized mobile devices with headphones for this purpose. These audio tours, which typically require visitors to manually enter codes displayed near specific locations and/or exhibits, offer visitors on-demand , information, commentary and even music. While these hardware devices have evolved from linear cassettes to non-linear digital CDs and MP3 players, making the user-experience more intuitive and more flexible, the concept has remained fundamentally the same – provide visitors with access to additional auditory content relevant to single items, or less commonly, exploring connections between multiple items.

More recently, some museums have started offering handheld devices which allow visitors to specify exhibits for which they would like to subsequently access additional media. Perhaps the best known example of this is the Experience Music Project (http://www.emplive.com/visit/about_emp/tech.asp) in Seattle, which not only provides supplementary audio content to exhibits, but also allows users to electronically "tag" items which they can then explore in more detail using a separate electronic workstation at a later time.

Other museums have also sought to offer electronic guides to visitors that not only provide supplementary information on the spot, but also allow them to retrieve related information later. The Exploratorium in San Francisco has conducted a study (Hsi 2003) of visitors' use of this strategy within their science center. In this study, location-aware Pocket computers provided visitors with web-based information about aspects of the museum including history, annotations and suggested explorations. Content, including audio, video and text, was delivered to the devices wirelessly. Two themes emerged in this study. First, visitors said that they technology isolated them. In order to hear audio, they wore headsets which tended to separate them from their surroundings. Additionally, visitors tended to focus on the device, taking away their focus from the rest of the museum. Second, visitors had trouble connecting the virtual content on their handhelds with the real content in the museum. Despite these two shortcomings, however, the visitors did say the technology encouraged them to view exhibits in new ways and try things that they hadn't before.

As museums explore these new technologies it is important to consider the affordances of the specific technologies and how they can meet the goals of the museum's physical space while providing an additional layer of engagement. In exploring this notion, other museums have tried using roaming handhelds in different ways. In a departure from the guided tour metaphor, one design (http://woz.commtechlab.msu.edu/courses/theses/scavengerhunt/) was created at the Chicago Historical Society in the form of a scavenger hunt. The goal here was to create something more game-like that would attract the interest of younger visitors. The scavenger hunt would pose one of 10 questions such as, "Find this cup [picture shown] and see the logo and mascot carefully. Which famous brand's cup was it? [multiple-choice answers provided]". Players would earn points for correctly answering each of the questions. They found that students aged 9-13 liked the technology and actively sought the answers rather than simply guessing. However, from a museum education and design perspective, this scavenger hunt strategy may be viewed as counterproductive. It encourages students to see the museum as a bunch of disconnected, decontextualized artifacts. Many museums actively discourage the scavenger hunt motif because it does not encourage students to think deeply about what they are looking at or promote thoughtful inquiry. Yet, the concept of integrating a game into the museum space to engage students in this age range is intriguing, as many of them use and enjoy handheld games.

Museums have not employed these new technologies to encourage interaction with other museumgoers. For the most part, as noted in the Exploratorium study (Hsi 2003), the technologies do exactly the opposite, fostering a more private and isolated experience. Yet the field of computer supported collaborative learning certainly provides evidence that collaborative learning is effective in encouraging people to think critically about important ideas, and perhaps this notion should be more seriously considered in the informal learning space of museums.

MYSTERY AT THE MUSEUM

Building on of our experiences using location-aware handhelds for learning experiences at schools and nature centers (Klopfer and Squire 2003), a new game was designed for the Boston Museum of Science. The primary design goals were to:

- Engage visitors more deeply in museum exhibits – get visitors to explore and think about specific exhibits that they had not seen before
- Engage visitors more broadly across museum exhibits – get visitors to see connections across the exhibits of the museum, and explore parts of the museum that they had not visited in the past
- Encourage collaboration between visitors – get visitors to discuss ideas to promote engagement

In choosing a target audience for the game, we settled on the core museum going contingent of families – specifically late elementary through middle school aged students and their parents. An additional goal was then added to the project of increasing meaningful collaboration and interaction between parents and children around science and inquiry. These goals are consistent with the recently introduced AAAS supported Science Everywhere initiative (http://www.tryscience.org/parents/parent.html).

Through an iterative design process involving museum educators, learning scientists and technologists, and drawing upon our previous experiences in handheld game design (e.g. Klopfer and Squire 2003) and a growing body of knowledge on learning through gaming (Gee 2003), we designed an interactive mystery game called Mystery at the Museum (the High Tech Whodunnit), which was designed for synchronous play of groups of parents and children over a two to three hour period.

The fictitious premise of Mystery at the Museum (M@M) was that a band of thieves (The Pink Flamingo Thieves) had left their calling card (a pink flamingo) in an exhibit case indicating that they had stolen a priceless object from the museum and replaced it with a replica. The players (in M@M) have been brought in as a team of experts to try to solve the crime, apprehend the criminals, and identify and retrieve the stolen artifact. Each player took on one of three possible roles – a technologist, a biologist and a detective – each with special capabilities. The interdependencies among the roles encouraged different roles to collaborate throughout the game. Logistically, players were organized as six players (three pairs) per team with each pair (parent and child) using one one Pocket PC and a walkie-talkie. Players have many different ways in which they can collect clues - including interviewing virtual characters (unique to each room within the museum), collecting virtual clues found in exhibit halls, analyzing samples using virtual instruments, and understanding information from exhibits throughout the museum.

The Pocket PC used Wi-Fi positioning to determine what room in the museum it was in. It could then provide the players with information about dynamic virtual characters and objects in the room with which they could interact. These virtual objects and characters in turn referred to and complemented real, physical components of museum exhibits which had been incorporated into the story. The fundamental interactions that were inherent to the game were as follows:

- In each room was a set of *virtual characters*, which could be "interviewed" by clicking on them. The characters would provide a monologue in the form of text, often accompanied by pictures. The characters could move rooms over time, and players in different roles might receive different information from the characters (i.e. a character might tell something quite different to a detective researching a case, than they would to a biologist). Many of the virtual characters referred to other exhibits or rooms.
- In many rooms there were *virtual objects*, which could be picked up and examined. Each had both a textual description and one or more images associated with it. Players could also "show" virtual objects to characters who would then react accordingly, often providing additional information. Some of the objects related to nearby exhibits.
- In several locations *virtual equipment* (e.g. a scanning electron microscope) could be used to obtain further information about the virtual objects. Where possible the virtual equipment was placed near real equipment of similar types (like the SEM). Equipment "use" was restricted to certain player roles as appropriate.
- Several items in the museum were tagged with *infrared tags*. These tags provided the players with virtual samples taken from those particular items (e.g. fingerprints from a glass case).
- Players could exchange objects and interviews with each other through *localized infrared beaming*. In many cases one role was the only one capable of retrieving a sample (e.g. the detective who could get a splinter from an unconscious guard), while another role was the one who could use equipment to analyze it (e.g. the technologist capable of using the virtual SEM).

The game was completed when players had accumulated enough evidence to obtain a virtual warrant for the arrest of the culprits. One of the organizers played the role of judge who considered the information presented orally by the players and, if sufficient evidence was presented, beamed the players an arrest warrant

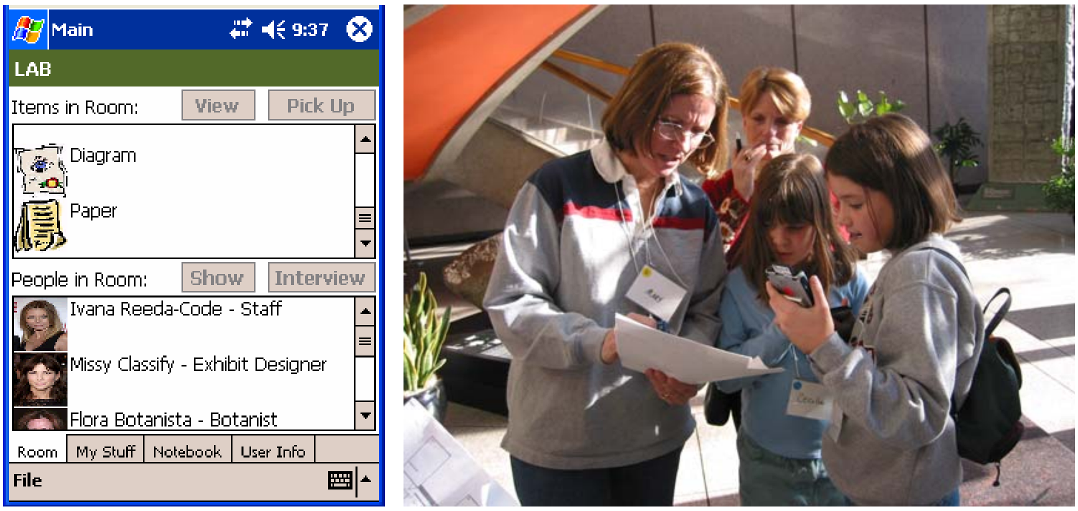

Figure 1. A screen shot showing virtual items and characters in the room (left) and a group of players collecting clues in the museum (right).

IMPLEMENTATION AND DATA

M@M was played at the Boston Museum of Science on two successive weekend afternoons with a group of approximately 20 parents and children each day. Parents were always paired with their own child. While several of the parents and children knew each other, the majority did not know any of the other participants before the game. The groups were subdivided into teams of six (as mentioned above). In cases with uneven numbers, a single redundant role was added to a team. After players were introduced to the "mystery" and given a brief tutorial of game mechanics, they were given one hour to play the first phase of the game. After this first hour of game play, players regrouped in the meeting room, checked in with the organizers for 5-10 minutes and then went back into the exhibit halls to play the second half of the game for an additional 30 minutes. At the end of the game the players met again to discuss the process, complete surveys. A sample of participants were then interviewed by the research team. In order to determine how well the game met our design goals several data sources were triangulated to determine emergent themes. These sources included video tapes that tracked groups as they went through the entire process, pre and post game surveys of both parents and children on interests in the museum, technology and collaboration, and video tapes of the post game group debrief and individual interviews.

RESULTS

Deep and Broad Engagement

Players in the game were required to visit a wide variety of places in the museum, and to examine exhibits closely to find and understand some of the "clues". Several codes, for example, were woven into the storyline (the thieves used codes to communicate with each other). Interpreting these codes required players to find and connect information from several exhibits on mathematics, communication, and models. The feedback from the participants suggested that this combination of depth (examining some exhibits in detail) and breadth (thinking more broadly about multiple exhibits) was engaging and effective in encouraging them to think about the museum's exhibits. This can be seen in the interactions of one of the groups searching for information to help them decode one of the clues which the thieves left behind:

Mom 1: We're looking for codes to help us decode this. If anyone finds stuff let us know [looking around]

Girl 2: Over here! Over here!

Mom 1: [Boy2] look in the 14th century [points to chronological history of mathematics]

Boy 2: Look Look. Water and dice like on the code.

Dad 2: [reads information about the code to himself and then applies that to the code "written" on the back of a virtual receipt] In an … hour.. [points to a part of the exhibit and speaks to the group]… it is telling him when to meet by the water. An hour after close.

This interaction shows how the teams worked together to discover and apply information from real exhibits in order to interpret the virtual information which in turn fed back into their game play strategies. During the group debrief discussion following the game, these feelings of connection with the museum were further conveyed. "…We did see parts of the museum we weren't aware of," said one of the parents addressing the variety of new exhibits they saw. A child commented that he, "hadn't ever seen the monkeys," which are one of the few live exhibits in the museum, and are tucked away in an area that is easy to miss. A parent noted on behalf of herself and her child, "We come a lot, and I still saw stuff in exhibits that I had never seen before." Another parent echoed, "I learned things that I had never seen before, like reading about the mummy or the banana tree. It made me read things that I wouldn't have otherwise."

Collaboration Across Roles

The roles in the game turned out to be extremely effective in engaging the pairs of participants with one another. Each individual role was forced to collect and share information to successfully solve the case. Here one group has met up after collecting information separately.

Boy 3: Have you been to the mummy?

Mom 2: Yes we went there.

Boy 3: They have to go there since they're the biologist. It is upstairs…

Boy 1: Let's give you [the Technologist] the splinters so you can look at them with the microscope.

Mom 1: We got the hobo code but we can't fully decode it. What do you think this means? [beams to other groups so that they can all look at the picture]

Often the groups concluded that it was beneficial to move around the museum in groups which included multiple roles so that they could collaborate to solve the problems. As one parent said, "In the second part we all went together to every room or even though we might not have needed everyone in each room we did better as a group." One of the senior museum educators further commented, "…sometimes people have trouble with the logical reasoning… [but in this group] they saw that one person could get what the others couldn't and they got the power of roles. Then they started using the beaming and they got that roles idea and off they went." The interdependence of roles served as the starting place for collaboration which then promoted more general collaborative problem solving. It is interesting to note that in the post-game surveys many participants wrote that they felt that their role was the most important in the game for one reason or another. This was consistent across all of the roles, showing that the roles had fostered players' sense of a unique contribution in addition to promoting collaboration.

Parent Child Interactions

Feedback from parents was quite positive in terms of how they felt it engaged them and their children. Parents commented on the appeal of different levels of complexity within the game, with tasks that encouraged them as adults to take an equally active, but different, job from their children. For example, in many cases the children were the ones who collected evidence with the Pocket PC, while the parents frequently organized the investigation and helped them physically navigate the large museum space. One parent of a 14 year old boy noted, "this is the longest substantive interaction I've had with my son in years without fighting." While children similarly noted, "my mom actually had a reason to be here [to help me figure out part of the game]".

CONCLUSIONS AND NEXT DIRECTIONS

This implementation of Mystery at the Museum shows great promise for interactive games in a museum setting. Museum educators, parents and children were all pleased with the way that it engaged them with individual exhibits, the larger museum space and with each other. There were other positive outcomes which were not originally designed into the experience. One mother (a physician) noted that while her colleagues had all used PDAs (like the Pocket PC) in their practice, she had been too afraid in the past, and now was willing to give it a try. A 10-year old girl similarly noted that she was not "the techie in the family" and often felt left out by technology, but that during this experience, she "really got it." These results suggest that further explorations of technology-based museum experiences of this type are wholly appropriate. There are many design issues to be considered in the future including how the roles should be designed, how this model could be adapted to less synchronous implementations, and how portable the model is across institutions. Of particular interest is how this game can be adapted to museum environments in which synchronous runs of the game are not feasible or desired. There are several options for making these kinds of adaptations. One solution would be to allow players to start the game at any time, but limit their interactions to other players who started within an adjacent window of time. Alternatively, the narrative may be adapted such that it is dynamic and responsive to the actions of the current players. As we did in the original game, we can look to other gaming genres, which have conquered similar problems. The quests of many massively multi-player online roleplaying games, which are constantly unfolding, have much to offer in this regard. These ideas will be considered in future investigations.

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Progressive Refinement of a CSCL-Based Lesson Plan for Improving Student Learning as Knowledge Building in the Period for the Integrated Study

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Abstract. Although constructivism has been prevailed across schools in Japan, what they call constructivism is a "shallow" one (Scardamalia, & Bereiter, 2002). In collaboration with teachers at a laboratory school, we have been conducting design studies on a lesson for knowledge building from the perspective of "deep" constructivism. For embodying such a new lesson, a CSCL technology called Knowledge Forum® has been introduced. Through the progressive refinement of lesson plans, we have been involved in creating pedagogical design principles (Linn, Davis, & Bell (Eds.), 2004) by referring to the metaprinciples on knowledge building (Scardamalia, 2002). In this report, we describe our refinement process of a fifth-grade lesson on genetically modified foods through two years, and discuss how the pedagogical design principles can be transformed into design elements.

Keywords: knowledge building, design principles, design studies, the period for the integrated study

LEARNING AS KNOWLEDGE BUILDING

In the educational reform debate in Japan, people are still in puzzlement with regard to the unsolved dichotomy in decision making: intellectual curiosity vs. basic skill training. In 2003, the Ministry of Education, Science, Sports, and Culture reformed their national guideline by introducing a totally new course called "the period for the integrated study." For deploying such a new part in the existing curriculum, the ministry reduced the time for other subjects by 30 % then cordoned more than 100 class hours a year from the third grade through the ninth grade (i.e., elementary and junior high schools). They are planning to gradually extend this curriculum to the tenth through twelfth grade (i.e., senior high schools).

What is currently happening, on the contrary, is that some schools just go back to the basics by using the period to make students engage in skill acquisition. The schools claim that they need to educate students basic skills rather than having students think of what to learn by themselves. The phenomenon like this manifests that many schools cannot have their visions on the period for the integrated study as time for students to engage in meaningful learning. A reason behind the situation is that schools do not have sufficient resources to establish their own curriculum based on a new epistemological idea on students as life-long learners or knowledge builders.

The goal of our research project funded by the ministry of education, science, sports, and culture in Japan is to establish a curriculum in the period for the integrated study by designing and progressively refining lessons based on knowledge resources by practitioners and learning scientists (e.g., Oshima, Oshima, Inagaki, Nakayama, Yamaguchi, Takenaka, & Murayama, 2003; Oshima, Oshima, Murayama, Inagaki, Takenaka, Nakayama, & Yamaguchi, 2004). The epistemology of learning we have adopted to our design studies is "learning as knowledge building (Scardamalia, & Bereiter, 2002)." In the view of learning as knowledge building, we see students work at the *frontier* of their shared understanding and collaboratively build their knowledge on the top of their current understanding. Scardamalia (2002) describes twelve metaprinciples ("determinants" in her original word) for making the classroom a knowledge building community. A central notion of the metaprinciples is "collective cognitive responsibility." People who are identified to engage in knowledge building should be building knowledge for the purpose of contributing to the advancement of collective understanding in their community. The notion is decomposed into twelve principles as follows:

1. *Real ideas, and authentic problems*. In the classroom as a knowledge building community, learners are concerned with understanding based on their real inquiries. Problems usually used in the classroom are far from students' real concerns with the world they live in. On the other hand, if students are allowed to pursue any

topic with no tools for their learning, the activities do not support learning or knowledge building. Thus, we need to scaffold students to be keen on their inquiries and articulate their inquiries as pursuable problems.

2. *Improvable ideas*. Students' ideas on their learning materials and problems are regarded as improvable objects. Ideas are objectified and shared in some ways as conceptual artifacts (Bereiter, 2002) so that students can engage in discourse around them.

3. *Idea diversity*. The diversity of ideas raised by students is a natural and necessary context of knowledge building in the classroom. In didactic instruction, teachers take cognitive responsibility to manage the diversity, often ignoring it or subordinating it to their predetermined agenda. In the knowledge building classroom, students themselves take on the responsibility for managing their ideas to improve collective understanding.

4. *Rise above*. Through the improvement of ideas or understanding, students create more inclusive syntheses or super-ordinate concepts by summarizing previous ideas.

5. *Epistemic agency*. Students themselves manage how their knowledge could be advanced. They coordinate their personal ideas with others, and also monitor how their collaborative efforts proceed. These tasks require them to exert cognitive strategies for collaborative problem solving.

6. *Community knowledge, collective responsibility*. Students' contribution to improving their collective knowledge in the classroom is the primary purpose of the knowledge building classroom. The shift in their recognition from "learning as the improvement of individual knowledge" to "learning as individual contributions to the collective understanding" is crucial.

7. *Democratizing knowledge*. All individuals contribute to the knowledge advancement in the classroom in various ways. As designers of knowledge building environments, we must be carefully concerned with how students' group works can contribute to their collective knowledge advancement.

8. *Symmetric knowledge advancement*. A goal for knowledge building communities is to have individuals and organizations actively working to advance their knowledge, and have their advances at the same time serve to advance the knowledge of others. Thus there is reciprocity in knowledge work, with the outputs of one group helping another group, and creating a whole that is greater than the sum of the parts.

9. *Pervasive knowledge building*. Students acquire a disposition to contribute to collective knowledge building. It is not something they do at special moments, or in special classes, or during particular curriculum activities. Rather it is integral to how they approach all knowledge problems and it is extensible across contexts, grades and working contexts.

10. *Constructive uses of authoritative sources*. Problems of passive reading and inert knowledge are frequently reported in the literature. Another form of passivity comes from treating text as the ultimate, authoritative source. In the knowledge building classroom, students are encouraged to use resources as conceptual artifacts that are treated as objects of inquiry, and juxtaposed against their personally constructed artifacts. In terms of the van Dijk and Kintsch (1983) model of reading comprehension, knowledge builders actively create both a situation and text model, working actively with both models in ways that lead to more effective learning. Visiting experts in the classroom are not teachers who know everything, but co-researchers. All members, including the teacher, sustain inquiry at the cutting edge of their understanding.

11. *Knowledge building discourse*. Students are engaged in discourse to objectify their ideas, to share with each other, and to improve the knowledge advancement in the classroom. Scientific discourse is a typical form of knowledge building discourse. Conceptual artifacts in scientific discourse are frequently objectified as propositional knowledge. There are strategic discourse patterns for improving the conceptual artifacts (Bereiter, 1994, 2002). Appropriate scaffold supports encourage students to engage in such progressive discourse on their ideas.

12. *Concurrent, embedded and transformative assessment*. For the knowledge advancement, appropriate monitoring is crucial. Students need to look at a total view of their understanding then decide how to proceed in their knowledge building. They create portfolios, comment on each other's work, and engage in a variety of self-monitoring activities. They do not wait for outside experts to evaluate them, but rather evaluate their own progress on an ongoing basis. Accordingly, they are often able to exceed the expectations that others set for them. This collective effort by students to reflect on their collective knowledge is facilitated by the engagement of the teacher as a member of the knowledge building community, not the sole community member responsible for evaluating progress.

In this study, we transformed the twelve metaprinciples into several pedagogical and pragmatic principles (Linn, Davis, & Bell (Eds.), 2004) so that we can concretely design lessons in the classroom. Furthermore, for supporting our lesson plans for knowledge building, a CSCL technology, Knowledge Forum® was implemented in the classroom. In the next section, we describe what pedagogical and pragmatic principles we adopted to our lessons and how we used the CSCL technology to empower student learning as knowledge building.

PEDAGOGICAL DESIGN PRINCIPLES, AND KNOWLEDGE FORUM® AS A TECHNOLOGY TO SUPPORT STUDENTS ENGAGE IN KNOWLEDGE BUILDING

Twelve determinants (Scardamalia, 2002) are general principles across a variety of contexts of knowledge building. Whereas they are useful to identify how much closer our communities are to the knowledge building community, they are somewhat too general to design actual lessons or classrooms at schools. What we had to do at the first step to adopt the knowledge building determinants to our design studies was to transform the determinants into pedagogical or pragmatic principles (Linn et al., 2004). The pedagogical design principles should be descriptions on how and what we need to prepare for supporting student learning as knowledge building. They should be articulate enough and easier to understand for teachers or supporters to take their instructional actions. In our studies on the period for the integrated study, we transformed the determinants into the following four pedagogical design principles.

Student ideas should always be at the center of their practice. Knowledge building is a type of practice in which learners engage in knowledge advancement based on their ideas. In Japanese classrooms, student ideas are sometimes treated as important resources, but cannot exist in the center of their practice all the time. Their ideas are used by teachers to introduce predetermined learning goals, but rarely revisited by students. The idea-centered classroom is, therefore, not familiar to students as well as teachers. For getting student ideas easily elicited and existed at anytime students liked to work on them, we implemented Knowledge Forum® as a medium for students to externalize their ideas in a communal database where they could revisit their previous ideas to collaboratively revise or organize the ideas for their further knowledge advancement. In Knowledge Forum®, students could report their ideas in the form of multimedia notes with scaffolds for their constructive discourse on their own ideas, and revisit their own and others' notes to organize ideas by themselves and their colleagues and build new ideas on their previous ones. Their discourse and manipulation in organizing and building on their ideas are represented as different types of notes in the database and configuration of notes in a hierarchical structure of discussion spaces (called "views").

Student learning should be structured in such a way that every student should have her/his cognitive responsibility. In the knowledge building community or team, every participant should contribute to their collective knowledge advancement. In other words, every participant should have her/his *cognitive* responsibility. In professional organizations, people with different types of expertise are involved in the collective problem solving in this way. In classrooms, however, students are not experts, and do not have recognition on how their own learning is related to others'. For making every student develop their expertise or ideas to contribute to their classroom knowledge, the task structure in which students work on their own ideas and the activity structure by which they collaboratively work on their ideas were designed as follows. Tasks students challenge in the classroom should be *authentic and real problems* elicited from their ideas related to their study topic. Furthermore, the problems should be shared by students to use their expertise to contribute to the advancement of their collective understanding. We, therefore, asked students to generate their *knowledge-based questions* rather than *text-based questions* (Scardamalia, & Bereiter, 1992). In addition, we used collaborative learning by small groups (three or four students per group) as a minimum learning unit in which students with different ideas reciprocally helped one another to solve their challenging problems.

Communication at different group sizes should be encouraged and supported with different media. The classroom knowledge is advanced through student collaboration with different types of discourses happening in the classroom. In Japanese classrooms, student discourse activities are mainly happening at small group or in the classroom as a whole. In our design studies, several cognitive tools such as worksheets for groupwork and Knowledge Forum® were implemented in lesson plans. The implementation of Knowledge Forum® particularly made it possible for students to engage in inter-group discourse during their groupwork. Three different layers of communication, i.e., intragroup, intergroup, and the classroom discourse, were structured for students to gradually transform their *individual* ideas into *more collective* ideas.

Students have opportunities to think of their problems, organize ideas, and reflect on their progress toward what they want to understand. Working on ideas is a really metacognitive aspect of learning. Teachers are usually taking the metacognitive role of student learning. Students are not asked "how would you like to learn on this issue?" or "what do you think we should do for understanding this issue further?" Teachers think that answers to these questions should be included in their material studies and designed as part of their instructions. Teachers know that students bring a variety of ideas related to the study topic, but that it is not possible to expect all beforehand. High quality of teachers redirect a variety of student ideas toward the learning goals predetermined in lesson plans, but rarely take this role over to students themselves. In this study, we designed lesson plans so that students regularly take the metacognitive role of their own learning and a teacher would play another role of supervising students' activities of eliciting problems to be pursued, organizing ideas collaboratively, and reflecting on progress in their learning.

DESIGN STUDIES IN THE PERIOD FOR THE INTEGRATED STUDY: PROGRESSIVE REFINEMENT OF A LESSON PLAN ON GENETICALLY MODIFIED FOODS

A topic we chose for our design studies was "genetically modified foods (GM foods)." GM foods is one of global and authentic issues in our life, and has been scientifically discussed on its advantage and disadvantage (Bell, 2004). In Japan, the Ministry of Health, Labour, and Welfare established their criteria to test GM food safety. Some GM crops have been confirmed their safety and allowed to be put on the market. The reality is, however, that many food product companies do not like to use GM crops as ingredients of their products because their customers are still very anxious about the safety. In our designed lessons, fifth grade students in a classroom at a laboratory school challenged this issue by identifying problems around the issue, conducting research on the problems, and utilizing their knowledge to generate their own solutions to the problems. In the first year, based on the preceding research and practices (e.g., GM foods lessons in WISE project), we designed a lesson plan by implementing design elements (Collins, Joseph, & Bielaczyc, 2004) with the four pedagogical design principles described above. During the practice of lessons, we videotaped how students engaged in learning in the classroom, and how a teacher supported their learning. Analyses on the video records and notes reported on Knowledge Forum® helped us to diagnose our lesson plan and interventions we did during the practice. In the second year, we revised our lesson plan based on our diagnosis of the first year's plan, and conducted again the practice in another fifth grade classroom with the same teacher. Data collected in the second year were compared with those in the first year for evaluating the revision of the lesson plan.

The First Year's Design Study

The Classroom Description

Forty-one fifth grade students (21 females, and 20 males) were engaged in their learning on GM foods in the period for the integrated study. The lesson started in May and continued through July for 23 class hours (A class hour was 45 minutes long.). Students were expected to know about the word but not any scientific mechanism or why they have been being developed. In glossary stores, labels of products usually described that products did not include any GM crops. So, it was difficult for students to actually see food products including GM crops. Parents were concerned with the products with GM crops as ingredients, and might think that the products were not safe enough and caused some allergies to people who were vulnerable to GM crops.

Designing a Lesson on GM Foods

We developed design elements based on the pedagogical principles we adopted, and designed a lesson in the first year as follows.

Student ideas should always be at the center of their practice. The lesson started by asking students of what they thought on GM foods. The teacher created a *concept map* (on the blackboard) based on students' ideas for representing what they knew, and having them share their ideas with each other. Their *classroom concept map* was used further to elicit issues they had to pursue for further learning by themselves. The teacher coordinated their discussion on what issues to be further studied. Students found three issues to be valuable for them to further study: (1) scientific understanding on GM foods, (2) advantages and disadvantages on GM foods, and (3) current situation of GM foods in their real life. Each student chose one of the issues as her/his own theme to be pursued in small groups (The activity structure of small groups are described later.), and their ideas were regularly reported on Knowledge Forum® so that they reflected on their progress and others' at anytime they wanted to do so. The teacher and supporters also created a view on classroom activity reports for students. Pictures on the blackboard and how students were engaged in their learning in each class were reported on the view.

Student learning should be structured in such a way that every student should have her/his cognitive responsibility. Students were not asked to do tasks given by the teacher, but to generate issues for their own study by themselves and take a part of the classroom research. Because they chose their own issue by themselves, motivation to their study was high. In addition, we designed the basic unit of their learning in small groups. A group was composed of three or four students who chose the same issue to study. Students were encouraged to work collaboratively and to report their ideas on Knowledge Forum® as group notes. The teacher supported students to report their collaborative ideas by giving them worksheets where they could write their individual ideas to share them with other group members before reporting on Knowledge Forum®. Ideas reported by groups within/between issues were discussed at different sizes of their classroom community (see details in the next section). In the final stage of their learning, based on their studies on GM foods, students were encouraged to discuss how they should live with this new technology as consumers of food products. In a view called "GM food conference," students expressed their opinions and their reasons or information resources by citing notes on Knowledge Forum® and references at the school library.

Communication at different group sizes should be encouraged and supported with different media. We designed three different layers of communication: intragroup, intergroup, and the classroom discourse. The intragroup communication was mainly based on oral discourse in face-to-face. We implemented worksheets for individual group members to express their ideas before talking to one another within groups. The written discourse by individual group members were used as objects to share and have discourse on for constructing their collaborative ideas.

The collaborative ideas by different groups were further shared to organize as more collective ideas among different groups within the same issues or between different issues. Several scaffolds (a function prepared in Knowledge Forum®) were used for helping students report their ideas as structured arguments. Before starting their groupwork, students discussed how to report their group ideas so that they could share them with one another in a meaningful way. Different structures of arguments were found to be needed in different issues because they applied different types of research methodologies to the three issues. Based on their discussion, the teacher and supporters created different types of scaffolds (a type of tags by which students wrote their ideas in subsection of a note), and students used the scaffolds in writing their arguments in notes. In organizing notes by different groups within the same issues, another function in Knowledge Forum®, "*rise above*," was used. Students could collect similar ideas to drag multiple notes in a "rise above box" and report a summary on their ideas in a superordinate note. The activity of manipulating notes by different groups within the same issue was conducted through the supervision by the teacher. The teacher projected a target view on a screen in front of students working on the issue, and asked students to discuss how to organize their ideas in notes. After organizing their ideas in their target views, students further discussed with students working with different issues on what they found and how their findings were related to one another in the classroom as a whole.

Students have opportunities to think of their problems, organize ideas, and reflect on their progress toward what they want to understand. During their groupwrok, students were encouraged by the teacher to regularly reflect on their progress by reading, revising, and building on notes by themselves and other groups. Some benchmark lessons (Brown, 1989) were designed in our lesson plan. Because the classroom activities were dynamic, we changed our lesson plan by implementing more benchmark lessons at anytime we thought that we needed to do so for students to share important resources or ideas with others.

Evaluation of Student Learning as Knowledge Building

We evaluated our lesson by two different types of analyses on student activities in the classroom. The first analysis was conducted on the quality of problems students had in their learning. Based on their discourse in notes on Knowledge Forum®, we identified four different levels of questions by referring to the categorization by Chan, Lee, & vanAalst (2001). Qualities of students' questions they pursued were compared across different views (or stages of learning). The second analysis was conducted based on our observation of the classroom and the discourse on Knowledge Forum® to figure out what events did happen in relation to the knowledge building determinants (Scardamalia, 2002).

Qualities of Students' Questions Identified in Their Discourse on Knowledge Forum®. Knowledge building is a unique type of cognitive activity, and can be evaluated only by analyzing a process by which learners manipulate their knowledge (Bereiter, & Scardamalia, 1993). One strategy for evaluating the process of knowledge building is to analyze what types of questions learners are engaged in (e.g., Oshima, Scradamalia, & Bereiter, 1996). Chan et al. (2001) analyzed questions that high school students had in their learning on the plate tectonics theory. They found that the high school students came to deal with higher qualities of questions as they proceeded their learning, and that the quality of their questions were positively correlated to the level of their final conceptual understanding. The four levels of questions identified by Chan et al. (2001) were as follows:

- *Level 1: Definition questions*. Students just ask the definition of the term or concept. The most typical and initial question in our lesson was "What is a genetically modified food?"
- *Level 2: Factual, topical, and general questions*. The second level is a type of question that reflects facts or general statements. In most cases, when students ask this type of questions, their idea is around some facts or topics. One example in our lesson was "What crops are genetically modified?"
- *Level 3: Puzzlement questions*. When students showed their puzzlement by collecting ideas by different members and recognizing some gaps among the ideas, their puzzlement was identified as level 3. In our lesson, after learning advantages and disadvantages on GM foods, they recognized some gaps between pros and cons. They could not figure out what further questions they should pursue for filling the gaps, but thought that the filling the gaps was important to them.
- *Level 4: Explanation-based questions*. When students identified inconsistencies or gaps between their ideas then proposed articulate questions for solving the problems, their questions were identified as level 4. Students could recognize the problem they had, and decompose the problem into tasks or questions that they should work on in the next step.

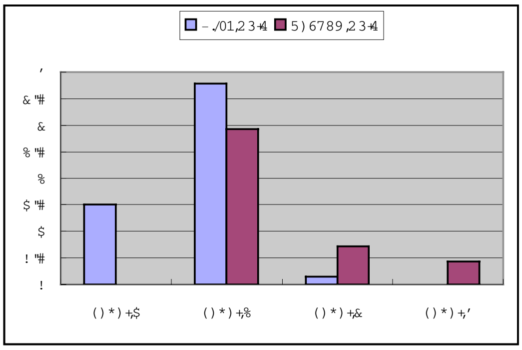

Figure 1. Mean Frequencies of Notes with Different Levels of Questions.

Two independent raters evaluated students' discourse in their notes. The agreement between the raters was .82. Their disagreement was resolved through their discussion. Frequencies of notes with different levels of questions generated by 14 groups of students were counted in the first and second half stages of their learning (see Figure 1). A 2 (Stage of Learning) X 4 (Level of Question) ANOVA on the note frequencies showed the main effect of Level of Question, $F(3, 104) = 29.3$, $p < .01$, and the interaction effect, $F(3, 104) = 3.5$, $p < .05$. The main effect of Level of Question manifested that students generated significantly more Level 2 questions than others either in the first or the second half of their learning. The interaction effect further manifested that they generated Level 1 questions significantly more in the first half of learning than did they in the second half. In sum, the statistical analysis on the frequency of different levels of notes students generated during their learning suggested that questions in their discourse on Knowledge Forum® was changed toward higher levels as they proceeded their learning. In a few notes, students were engaged in high quality of knowledge building activity through their explanations on what they had learned. In many notes, on the other hand, students were still concerned with factual or topical questions.

Students' Activities Related to Knowledge Building Determinants. During their discourse on the ideas on and off Knowledge Forum®, students were encouraged to consider relations among ideas and to propose new ideas from superordinate perspectives. Based on their own concept map, students elicited three issues they had to pursue: (1) "What are GM foods?" (2) "Why are they being developed?" and (3) "Do we have them in Japan?" The three issues were pursued by several small groups in different views. After their studies on the three issues, they shared their ideas and new understanding between groups in different views and gave comments on each other's notes. Their comments led note authors to further revise or add new ideas on the commented notes. Finally, in a view called "GM foods conference," students expressed their decisions on which position (positive or negative) toward GM foods and reasons for their decisions. A few groups of students manifested high quality of discourses on their decisions with reasoning elicited by high levels of questions (i.e., explanation-based questions). Here, we describe their discourse activities to figure out how students conducted their learning as knowledge building.

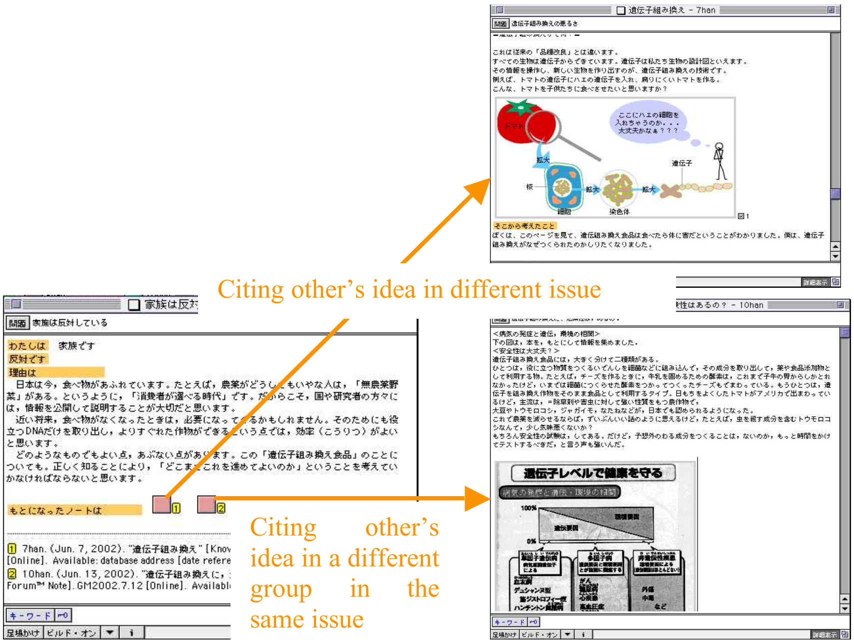

Figure 2. An Epistemic Agency for Knowledge Building Seen in Knowledge Forum® Discourse.

Students who engaged in discourse with Level 4 questions exerted the *epistemic agency* for knowledge building by effectively using functions prepared in Knowledge Forum®. An example of discourse by Group 14 is seen in Figure 2. The group expressed their negative position toward GM foods in the "GM foods conference" view. Their reasoning to make their decision was constructive rather than providing evidences that GM foods are not safe. In their discourse, they used three different idea resources. First, they used *their own idea* for their reasoning. Before expressing their ideas on GM foods in the conference view, they had studied how ordinary customers thought about GM foods by their interview research at a supermarket. Their conclusion was that Japanese customers could choose GM foods or organic ones with their preference in our current situation of food provision. Second, they also referred to *another group's idea on the same issue* to confirm their decision. Furthermore, they described how we can develop GM foods to provide good qualities of food products by citing *an idea in a note by a group that had studied another issue*, "Why are they being developed?". For group 14, the problem that they decided which position they should take toward GM foods was not a simple choice by showing their preference, but they recognized the problem that they had to consider different idea resources on GM foods to comprehensively understand GM foods. In other discourses identified as Level 4 question-based, we found the same tendency that students attempted to build structures of arguments with ideas from multiple perspectives.

Discussion

In the first year of our design study, we implemented four pedagogical design principles to consider design elements in a lesson plan on GM foods. Our analysis on student learning activities showed some positive findings and problems we have to further consider. First, the analysis on the quality of discourse in notes on Knowledge Forum® suggested that students succeeded in improving their quality of discourse as they proceeded their learning. This phenomena is not expectable in ordinary classroom learning. In the ordinary class, students recognize that they complete their learning in the end of the unit of a lesson. Therefore, students usually do not have further questions on their study topic. In our designed lesson, students saw their learning as progressive problem solving and continuously improved their discourse by generating higher qualities of questions. As we found in the ANOVA on frequencies of notes with different levels of questions, however, the tendency was not sufficiently strong in that we could not find a significant differences in note frequencies with Level 3 and 4 questions between the first and the second stage.

The descriptive analysis on students' discourse on Knowledge Forum® was conducted to further consider how more students can be involved in knowledge building discourse. The result manifested that students identified to generate Level 4 questions in their discourse made use of multiple ideas by referring to other groups' notes in different issues to construct arguments for their decision making. Thus, design elements based on our pedagogical principles (e.g., idea-centered discourse on Knowledge Forum®, and the activity and task structure) did successfully scaffold student learning as knowledge building.

The Second Year's Design Study

The Classroom Description

In the second year, the same teacher was in charge of the lesson for another fifth grade classroom on GM foods. The characteristics of students were considered to be similar to that in the first year. Thirty-five students (18 females and 17 males) participated in the lesson as part of their curriculum through 35 class hours.

Progressive Refinement on the GM Foods Lesson

The refinement on the lesson plan was discussed by the design team from the two perspectives: (1) refinement on our pedagogical design principles, and (2) refinement on design elements. Based on results of our analysis in the first year's design study, we concluded that our pedagogical design principles were effective but we could further refine design elements for more students to engage in their learning as knowledge building. Here, we describe how we refined our design elements in the second year.

Consequential task structure: From the GM foods conference to the consensus meeting. In the first year, the consequential task for students to challenge with their understanding on GM foods was how they as customers deal with GM foods in their real life. As we described in the section of the first year's design study, some groups of students recognized that the task required them of exerting their *epistemic agency* for knowledge building, i.e., monitoring what ideas they as a classroom community had and considering how they could integrate different perspectives to advance their understanding. However, the task requirement was not found to be articulate enough for most students to exert their *epistemic agency*. In the second year, we changed the consequential task from their decision making to the consensus making. In our real life, the Ministry of Health, Labour, and Welfare regularly opens the consensus meetings on GM foods for ordinary citizens. The main purpose of the consensus meetings is to articulate opinions customers have after learning about GM foods (i.e., This is what students did in the first year), and to consider what problems or issues should be further considered and solutions to the problems. In the consensus meetings, there is a coordinator who should manage progressive and productive discourse by customers by providing scientific evidences and helping them organize their arguments. We introduced the concept of the consensus meeting to students and encouraged students to engage in their learning by playing a role of coordinator of the consensus meeting. Students were expected to consider globally multiple perspectives on GM foods and propose solutions to problems customers are currently concerned with. Student activity required by the consensus task was considered to more directly elicit student *epistemic agency*.

Student learning activity structure: From three sub-projects to one big project. In the first year, students were divided into three sub-projects in each of which several groups of students conducted their research and reported their ideas and information in their project view. In the "GM foods conference" view, students were expected to collect ideas from the three different views to make their reasoning for their positions toward GM foods. The result of descriptive analysis on student discourse in the conference view manifested that only a few groups of students referred to ideas from multiple views. Thus, the result suggested that relatively large number of students were not using their colleague's idea resources effectively. In the second year, therefore, we refined the student activity structure by not dividing them into sub-projects but having them study on the basics of GM foods in the single view and share ideas with each other.

Evaluation of Student Learning as Knowledge Building

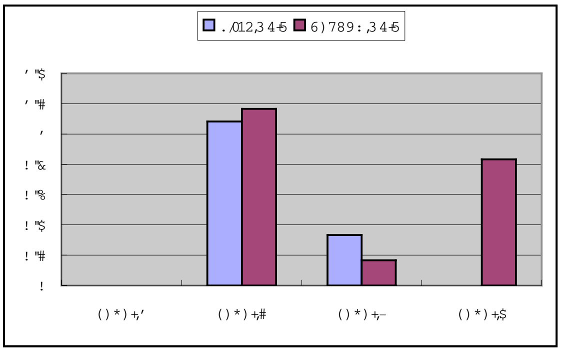

Figure 3. Mean Frequencies of Notes with Different Levels of Questions in the Second Year.

Qualities of Students' Questions Identified in Their Discourse on Knowledge Forum®. Students-generated notes were categorized into one of discourses with the four levels of questions by two independent raters. Their agreement was .93. Their disagreement was resolved through their discussion. Note numbers were counted, and a 2 (Stage of Learning) X 4 (Level of Question) ANOVA on note frequencies was conducted (see Figure 3). There were found to be a main effect of Level of Questions, $F(3, 88) = 12.1$, $p < .01$, and the marginal interaction effect, $F(3, 88) = 2.6$, $p = .06$. The results were summarized that students constantly generated more notes with Level 2 questions across the two stages of learning than other types of notes, and that they generated more notes with Level 4 questions in the second half than did they in the first half.

Students' Activities Related to Knowledge Building Determinants. In the second year, students were encouraged to propose solutions for people from different perspectives to make their consensus in the "Consensus Meeting" view. With our designed scaffold labels for their discourse, students attempted to make their reasoning by collecting ideas from their previous views as well as the current view. Since note numbers produced by students in the two years were different, we did not directly compare mean frequencies of notes with different levels of questions. A comparisons of proportions of groups that produced discourse with Level 4 questions between the two years (six of fourteen groups in the first year vs. six of twelve groups in the second year) did not manifest a significant difference, $\chi^2 = .13$, $df = 1$, $p > .05$. A remarkable finding was, however, seen in the comparison of proportions of notes in which students attempted to use ideas from multiple perspectives by citing others' notes. Chi-square analysis of note numbers showed that students in the second year produced significantly more notes considering multiple ideas (12 of 26 in the "Consensus Meeting" view) than did those in the first year (8 of 58 in the "GM Foods Conference" view), $\chi^2 = 10.36$, $df = 1$, $p < .01$. Thus, it was found that more students exerted the *epistemic agency* for knowledge building in the second year.

Discussion

Our refinement on the lesson by improving design elements, particularly the consequential task structure and the student activity structure, was found to be successful for improving student learning as knowledge building. In the second year, the improvement of student discourse in their notes was more robust than that in the first year. They did not only ask Level 1 question like "What is the genetically modified foods?" but also added more argument to produce higher levels of questions. The difference in note numbers between the first half and second half was found in the category of Level 4 questions. As discussed previously, the new consequential task requirement to propose solutions for people with different perspectives to make their consensus triggered students' *epistemic agency* to integrate ideas from multiple perspectives. The result of the analysis on numbers of notes in which students attempted to use multiple ideas supports our argument. In the "Consensus Meeting" view, significantly more notes were produced including multiple ideas. The activity structure, one big project, might have students more easily reflect how the classroom proceeded their learning. They did not need to switch back and forth different views for monitoring what ideas their colleagues were interested in or worked on.

GENERAL DISCUSSION

Our design studies across two years were aimed at designing a lesson plan for knowledge building in the period for the integrated study. We transformed metaprinciples on knowledge building into four pedagogical design principles for the classroom learning. The analyses manifested that our refinement on design elements based on our pedagogical design principles succeeded in facilitating student learning as knowledge building from the first year to the second. In this section, we again go back to the metaprinciples for discussing how our pedagogical design principles transformed the classroom into a knowledge building community.

"Real Ideas, Authentic Problems," "Improvable Ideas," and "Idea Diversity." Our pedagogical design principle on putting students' ideas at the center of the curriculum was successfully transformed into our lesson design across the two years. Students started their learning with what they had already known on the study topic

then proceeded their learning based on their own ideas and others'. Their ideas were externalized as discourse in notes on Knowledge Forum® and shared for further knowledge advancement.

"Rise Above," "Epistemic Agency," "Constructive Uses of Authoritative Sources," and "Knowledge Building Discourse." For triggering students' *epistemic agency* for knowledge building, we designed the lesson so that students were required of expressing their ideas through their discourse in proceeding their learning with the consequential task. In structuring arguments in their discourse, several scaffold labels (e.g., leading sentences, and headers representing thinking steps) were introduced to students. As a result, it was found that students were more likely to engage in knowledge building discourse (identified as discourse with Level 4 questions) through our refinement on the task structure and the activity structure from the first year to the second year. In their knowledge building discourse, students were using scientific evidence or archives from book references as conceptual artifacts (Bereiter, 2002) for advancing their reasoning. However, structuring collective ideas at the classroom as a whole was still managed by the teacher. Students were encouraged to rise above their individual group ideas by editing their views. In the next step of our progressive refinement, we like to consider design elements by which the teacher could take over the role of editing views (i.e., two-dimensional maps of different groups' ideas in issues students are concerned with) to students themselves. By sharing ideas in notes on Knowledge Forum®, students were found to intentionally engage in such an epistemic discourse in the classroom as a whole.

Table 1 shows an example of discourse seen in the classroom in 2002. In the discourse happening in the classroom, students were concerned with how to report their ideas developed through their groupwork. A student (Student 1) raised an issue that her group had opposite ideas to each other on GM foods. She told that it was problematic to report ideas as groups. The teacher accepted her problem in organizing a view on Knowledge Forum®, and further searched for ideas on how to solve the issue. Student 4 proposed that they were going to report individually based on their discussion in their groups. What we found from the discourse here is that students were acting as epistemic agents for their own learning. This type of epistemic agency was found across the two lesson units frequently but inconsistently. Students considered how to proceed their learning task by task, but did not consistently monitor a course of their learning in units. We have to further design elements so that students are naturally engaged in working on the management of their learning with their ideas represented on the knowledge medium. Editing the view may be a candidate element for us to ask them to do for facilitating their epistemic agency.

Table 1. An Example of Discourse by Students in Discussing How to Report Their Ideas in the GM Food Conference View.

Teacher	OK, [Student 1]. You have a question, don't you?
Student 1	Do you think that we are going to report ideas by groups?
Teacher	Yes, I do so.
Students 1	Well, if we are going to do so... When [Student 2] and I have the positive idea and [Student 3] has the opposite one, do you think that we have to choose one of the two?
Teacher	That's a really good question. I understand your concern very much. It is reasonable for us to predict that members in a group will have opposite ideas to each other. Some says positive whereas the others say negative... Do you have an idea on how to solve this issue, [Student 4]?
Student 4	I have an idea related to the question by [Student 1]. If we have the opposite opinions to each other in a group. why do not we report our ideas as individuals on the GM Food Conference View?
Teacher	Oh, you said that we report individually. It may be a way for us to go. I think that it is quite reasonable. Do all understand his idea? He proposed that we are going to report ideas individually if we have opposite ideas to each other so that we cannot report one note as a group. ...

"Community Knowledge, Collective Responsibility," "Democratizing Knowledge," and "Symmetric Knowledge Advancement." The student activity structure with collaborative learning within and between small groups made it more naturally possible for students to express their ideas to other members in their groups and their group ideas to other groups either on Knowledge Forum® or in the classroom. Our analysis of students' discourse in highly qualified notes manifested that they attempted to refer to ideas from multiple sources, and to take several different perspectives into consideration.

"Pervasive Knowledge Building," and "Embedded and Transformative Assessment." The pervasiveness is our final goal. It is not reasonable to expect that students can always have their tendency to deal with their

learning as knowledge building after their engagement in our designed lesson in such a short period of time (20-30 class hours). Therefore, we cannot evaluate if our design could satisfy this determinant. One surprising finding for us was that a few students reported how their learning in our designed lesson had been different from those they were usually taking in the classroom in the post interview. The assessment is another big issue for us to consider in the next refinement. In our design studies in the reported years, the assessment activity by students was designed by us. The teacher encouraged students to do their self assessment on the progress in their learning at the benchmark lessons. The more ideal situation should be that students can propose their colleagues or teacher to have opportunities to assess their progress through their regular monitoring. This is the highest level of metacognitive activity students can be involved in. We need to figure out the developmental trajectory of student *epistemic agency* for doing their own assessment through repeated refinement on our lesson.

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AUTHORS' NOTES

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Internal and External Collaboration Scripts in Web-based Science Learning at Schools

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Abstract. Collaboration scripts can help learners to engage in argumentation and knowledge acquisition. However, they might have differential effects for learners holding differently structured knowledge (internal scripts) on argumentation. We investigated how external scripts interact with learners' internal scripts concerning collaborative argumentation. 98 students from two secondary schools participated. Two versions of an external collaboration script (high vs. low structured) supporting argumentation were embedded within a web-based collaborative inquiry curriculum. Students' internal scripts were classified as either high or low structured, establishing a 2x2-factorial design. Results suggest that the high structured external script supported all learners, regardless of their internal scripts, concerning the acquisition of domain-general knowledge. Learners' internal scripts influenced the acquisition of domain-specific knowledge. Results from two case studies reveal differences in argumentation processes attributable to the learners' internal scripts. Results are discussed in terms of their theoretical relevance and practical implications for learning with collaboration scripts.

Keywords: Collaboration scripts, internal scripts, inquiry learning, science education, learning environments.

INTRODUCTION

Several studies have demonstrated that students frequently have problems discussing scientific evidence, particularly in relating evidence to theoretical explanations (e.g., Sandoval, 2003; Bell, 2004). Additionally, students often have difficulty engaging in fruitful argumentation. For example, arguments raised by one student often remain unaddressed by the student's learning partner(s), and obvious disagreements are often left unresolved. If not explicitly scaffolded, learners may fail to show substantive argumentation, leading to little acquisition of domain-general knowledge about argumentation. Low-level argumentation might be reflected in poor elaboration of learning contents and result in a limited acquisition of domain-specific knowledge.

Several instructional approaches have been used by researchers to address these challenges in learning through argumentation. For example, Suthers, Toth, and Weiner (1997) developed and tested Belvedere, a graphical argumentation tool where learners enter hypotheses and evidence into text boxes and specify the relationships between boxes using graphical arrows. This results in a network of nodes and links representing the various pieces of evidence that support or contradict a particular hypothesis. A similar approach has been taken by Bell (1997) in developing the "Sensemaker"-tool to help scaffold students' use of evidence within arguments within Web-based inquiry projects. Another promising approach to structuring collaborative argumentation processes in computer-supported collaborative learning is that of collaboration scripts (e.g., Weinberger, Fischer, & Mandl, 2004). Collaboration scripts provide learners with procedural guidance concerning specific discoursive processes they are to engage in during a particular collaborative learning task, thereby scaffolding the acquisition of procedural knowledge. Weinberger, et al. (2004) demonstrated that collaboration scripts can be designed and implemented within a web-based learning environment in order to evoke specific argumentative discourse processes, resulting in an acquisition of domain-general knowledge about argumentation.

We argue that collaboration scripts are a particularly promising approach when they are implemented within computer-based collaborative inquiry learning environments. In existing approaches like BGuiLE (Reiser, Tabak, Sandoval, Smith, Steinmuller & Leone, 2001), CoLAB (Savelsbergh, van Joolingen, Sins, de Jong & Lazonder, 2004), or WISE (Slotta & Linn, 2000), learners are provided with significant support concerning content-related learning, but rarely with specific instructional guidance concerning collaboration and argumentation. Instead, these environments typically provide rather open problem spaces, within which learners are relatively free to choose (a) *what* activities to engage in with respect to the problem at hand, and (b) *how* they want to perform those activities. While students are often required to work collaboratively with one or more peers in such activities, the lack of explicit scaffolds for collaboration could result in unequal participation of learning partners and ineffective argumentation. We claim that externally provided collaboration scripts can be designed to significantly improve both processes and outcomes of collaborative argumentation.

Still, learners may enter instruction with widely varying ideas about collaboration and different capabilities in argumentation. Such differences may call for different collaboration scripts in order to achieve the benefits of scaffolding described above. In the present study, we focus on the impact of learners' differently structured internal scripts (Schank & Abelson, 1977) concerning argumentation, meaning their individual procedural knowledge that guides them in argumentation tasks. We examine how these internal scripts interact with differently structured external collaboration scripts that are designed to help structure collaborative argumentation. This interaction is investigated with respect to both (a) processes and (b) outcomes of collaborative argumentation.

KNOWLEDGE CONSTRUCTION IN COLLABORATIVE ARGUMENTATION

Collaborative argumentation is a core activity practiced by learners who are engaged in collaborative inquiry learning environments. For example, by debating with peers about which piece of evidence supports a particular theory or argument, learners can acquire argumentation skills as well as domain-specific knowledge about the contents of their discussion (e.g., "arguing to learn" -- Andriessen, Baker, & Suthers, 2003). In formulating an argument, learners must explain their reasoning and thereby construct new knowledge (e.g., the "self explanation effect" -- Chi, Bassok, Lewis, Reimann, & Glaser, 1989). Concerning the specific process of argumentation, research is varied (see Stein & Albro, 2001), with at least two different approaches to argumentative knowledge construction. On the one hand, some researchers seek to assess the quality of single student arguments on the basis of the structural components they include. On the other hand, argumentation is often analyzed with respect to the different sequences of arguments like argument, counterargument and reply (Leitão, 2000; Resnick, Salmon, Zeitz, Wathen & Holowchak, 1993).

As an example for the first perspective, the argument scheme developed by Toulmin (1958) can be used to assess either written or oral arguments (e.g., Cobb, 2002; Bell & Linn, 2000) as well as to teach learners how to create complete arguments (e.g., Carr, 2003; McNeill, Lizotte, Krajcik, & Marx, 2004). Driver, Newton, and Osbourne (2000) point out that generating complete arguments leads to a deeper elaboration of the learning material resulting in an acquisition of domain-specific knowledge. According to the Toulmin model, an argument consists of up to six components. First, arguments are based on *data* representing evidence on which the argument relies. Second, arguments usually include a *claim* by which the speaker expresses his or her position. Third, arguments can contain a *warrant* that specifies why the data support the claim. Fourth, in order to highlight the validity of a warrant, arguments can contain a *backing*, which can be a reference to a general law, for example. Fifth, arguments can contain a *qualifier* that constrains the validity of the claim. Finally, an argument can contain a *rebuttal*, by which conditions are specified under which the claim is not valid. Since students in school may have difficulties in applying such a scheme to identify the components of an argument, it is useful to reduce the complexity of Toulmin's model. Therefore, similar to previous research (McNeill et al., 2004; Marttunen & Laurinen, 2001), we focus on three essential components of arguments: data, claims, and reasons (which comprise both warrants and backings)

With respect to the sequence of arguments, Leitão (2000) proposed a model of collaborative argumentation that takes different types of arguments into account. She distinguishes three types of arguments, namely (1) *arguments*, (2) *counterarguments*, and (3) *replies*. An argument represents an assertion that is preceded or followed by a justification. By generating a counterargument, a speaker can (a) shift the topic, (b) doubt the validity of the original argument, or (c) question the relation between the components of the argument (e.g., doubt that the provided data is really supporting the claim). Replies on counterarguments can also take on different forms. They can represent (a) a dismissal of the counterargument, (b) a local agreement with parts of the counterargument, (c) an integrative reply that combines parts of the argument and the counterargument, and (d) an abolishment of the original argument. Leitão (2000) claims that argumentation sequences of the structure "argument – counterargument – (integrative) reply" are most fruitful for collaborative knowledge construction, since they lead both learners to deeply elaborate content information, thereby acquiring domain-specific knowledge. Moreover, by engaging in meaningful sequences of argumentation, learners may internalize these processes and apply this knowledge even when not explicitly asked to do so, thereby acquiring domain-general knowledge about argumentation itself.

SCRIPTS FOR KNOWLEDGE CONSTRUCTION IN COLLABORATIVE ARGUMENTATION

External Scripts for Knowledge Construction in Collaborative Argumentation

Collaboration scripts are complex instructional means that (a) induce certain *activities* to be carried out by the learners, (b) prescribe specific *sequences* concerning when to carry out each activity, and (c) provide learners with *collaboration roles* specifying who of the learning partners is supposed to carry the related activities out (see Kollar, Fischer, & Hesse, 2003). Such scripts are here referred to as “external scripts” because they typically are – at least at the beginning of a collaborative learning situation – not represented in the learners’ cognitive systems but rather in their external surround (Perkins, 1993), possibly being gradually internalized the more learners are acting in accordance to the script’s contents. With respect to their *degree of structuredness*, external scripts can differ substantially. While some approaches provide rather rough constraints for specific activities, sequences, and roles (e.g., Baker & Lund, 1997), other approaches can be considered as being rather high structured (e.g., Pfister & Mühlpfordt, 2002), including very detailed instructions concerning which activities should be shown and when this should be the case. When reviewing existing collaboration script approaches it appears that scripts can be tailored to very different process and outcome dimensions, often accompanied by non-intended side-effects. For example, Weinberger, et al. (2004) demonstrated that an epistemic script aiming at facilitating content-related activities within triads of learners led to an increase of content-relevant talk but to lower content-specific learning gains and hampered transactivity, i.e. the mutual relatedness of the learning partners’ utterances.

Internal Scripts for Knowledge Construction in Collaborative Argumentation

It is reasonable to argue that collaborative argumentation processes are not only guided by externally induced scripts. Learners also bring internal scripts for collaborative argumentation into argumentative situations, which they have build up and continuously adjusted in earlier instances of argumentation. Similar to Schank and Abelson’s (1977) notion of “personal scripts”, we define internal scripts as the set of process-relevant knowledge that guides individuals in their acting in and understanding of particular situations, in our case in collaborative argumentation situations. We assume that these internal scripts on collaborative argumentation vary between individuals and that they are *structured to different degrees,* i.e. that different individuals have different knowledge about how to act in argumentative situations. For example, some individuals might know that reasons should be made explicit in arguments whereas others do not. Likewise, some individuals might have the aim to persuade their discourse partner resulting in producing counterarguments to all the partner’s arguments. Others might rather aim to find a consensus in an argumentative situation, resulting in an integration of the different standpoints. It is then unclear, how differently structured internal scripts play together with differently structured external scripts and how this interplay affects processes and outcomes of collaborative argumentation.

GOALS OF THE STUDY

The objective of this study is to analyze the effects of differently structured internal and external scripts on both processes and outcomes of students’ collaborative argumentation during learning in a web-based inquiry learning environment (Web-based Inquiry Science Environment; Slotta & Linn, 2000). On behalf of the *outcomes*, we focus on the individuals’ acquisition of domain-general knowledge on argumentation and of domain-specific knowledge. With respect to *processes*, we analyze the effects of internal and external scripts on particular argumentative moves. We set up two competing hypotheses:

Interactive effects hypothesis: A highly structured externally provided collaboration script will facilitate the acquisition of domain-general and domain-specific knowledge of learners holding low structured internal scripts, whereas a low structured external script will lead learners holding high structured internal scripts to acquire more domain-general and domain-specific knowledge. If true, this hypothesis could result from either the high structured external script compensating for the deficits of the low structured internal scripts, or because the highly structured external script unnecessarily puts constraints upon the learning processes of learners with high structured internal scripts.

Additive effects hypothesis: A high structured external collaboration script will support the acquisition of domain-general and domain-specific knowledge of all learners, independently from the nature of their internal scripts on collaborative argumentation, because even the contents of a high structured internal script will play out only when additional instructional support is provided.

In order to better understand the effects of the interplay of high and low structured internal and external scripts, the analyses are enhanced by a qualitative analysis of the discourse of two exemplary dyads.

METHOD

Participants. 98 students (grades 8 to 10) from five classes of two German Gymnasiums participated in the study.

Design. An experimental 2x2-factorial design was established with the internal scripts on collaborative argumentation (high vs. low structured) and the external collaboration script (high vs. low structured) as independent variables. Dyads were homogeneous with respect to the learners' internal scripts and gender and were randomly assigned to one of the two external script conditions. Learners were identified as holding a high or a low structured internal script by assessing their performance in a test, in which they were asked to identify "good" and "bad" argumentative moves (e.g., arguments lacking reasons or too short argumentative sequences) in a fictitious discourse excerpt about a science topic. The median score of 3.33 (SD = 2.41) was used as the criterion according to which learners were classified as holding either a low or a high structured internal script. This resulted in 48 learners classified as holding a low structured and 50 learners as holding a high structured internal script on collaborative argumentation.

Procedure. The study was conducted in two sessions. In the first session, which took part about two weeks before the actual collaboration phase, learners had to complete several questionnaires on demographic variables, prior domain-specific knowledge, and collaboration as well as computer experience. Most importantly, learners were asked to answer the test assessing their internal scripts. For the collaboration phase two weeks later, homogenous dyads were established with respect to the degree of structuredness of the learners' internal scripts. They then collaborated on the WISE-project "The Deformed Frogs Mystery", which is described below. Two versions of the "Deformed Frogs" project were realized, one containing the low structured and the other the high structured external collaboration script (see below). Dyads were randomly assigned to one of these two conditions. Time for collaboration was 120 minutes. Immediately after collaboration, learners had to complete questionnaires to assess their domain-general knowledge on argumentation and domain-specific knowledge (see below).

Setting and learning environment. Dyads worked on a German version of the WISE project "The Deformed Frogs Mystery". They were introduced to the phenomenon that many frogs with massive physical deformities had been found in the late 90's, for which several possible explanations exist. The project provided learners with two competing hypotheses, a *Parasite Hypothesis* and an *Environmental-Chemical Hypothesis* to be discussed against the background of various information (e.g., photographs, maps, reports), which learners could explore within the project. The curriculum project was segmented into five content-specific units, e.g. "What's the problem?", "Where are the deformed frogs?", or "What's in the water?". Learning partners of each dyad worked together in front of one computer screen and could talk face-to-face. A teacher was not present.

External collaboration script. The two versions of the external collaboration script were implemented in the "Deformed Frogs" project. At the end of each content-specific curriculum unit, the learning partners were supposed to discuss the two hypotheses on the basis of the information they had just viewed and to type their arguments. The two experimental conditions differed in the way how this typing and discussion phase was structured. In the *low structured* version of the external script, learning partners did not get further support than being asked to discuss the two hypotheses on the basis of the information of the particular unit.

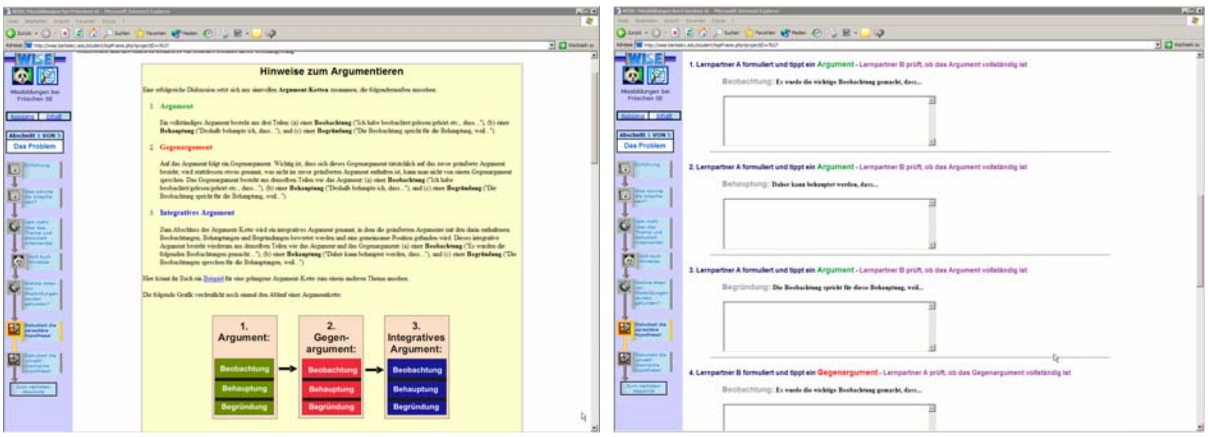

Figure 1: Screenshots of the high structured external collaboration script (left screen: introductory text; right screen: pre-structured text boxes to be filled in by the participants.

In the *high structured* (see figure 1) version of the external script, however, learners received additional guidance in how to discuss the two hypotheses, based on the models of Toulmin (1958) and Leitão (2000). More specifically, learners were prompted to create complete arguments in Toulmin's (1958) sense (data, claim, reason) and argumentative sequences according to Leitão's (2000) model (argument – counterargument – integrative argument). This was achieved by providing learners with an instructional text about these guidelines and by providing them with prestructured blank text boxes into which to fill in the requested argument components (e.g., data in text box 1, claim in text box 2 etc.). For each box, the script specified which learner had to create an argument component and provided him or her with sentence starters (e.g., "It was found that…" for data). In order to avoid biased information processing, the partners' roles concerning who had to advocate which hypothesis were switched several times. Also, script instructions were continuously faded out to avoid the problem of "over-scripting" (Dillenbourg, 2002). For example, at the end of the second unit, the high structured external script did not contain any sentence starters, and the textboxes were reduced to one for each argument, i.e. the interface did not force the learners anymore to split their arguments into data, claim, and reason. Anyway, learners still were reminded of those three components in the instructional text.

Instruments and dependent variables. The *domain-general knowledge about argumentation test* asked learners to mention what components an argument consists of as well as how a complete argumentative sequence looks like and to give examples for complete arguments and argumentative sequences. As a maximum, 12 points could be reached on this measure. Reliability of the measure was sufficient (Cronbach's $\alpha = .72$). The *domain-specific knowledge test* contained five open-ended questions. In the first four questions, learners were asked to reproduce the mechanisms that might cause the frog deformities according to the parasite and the environmental-chemical hypothesis. Learners received points for a reproduction of the mechanisms and for pieces of evidence they were mentioning by which the validity of the particular hypothesis could be assessed. The resulting subscale was termed *knowledge about mechanisms*. Overall, six points could be achieved on this measure. In the fifth question of the domain-specific knowledge test, learners were asked to reason about what could be done to definitely find out the reason for why the frogs are deformed. Here, learners could reach four points as a maximum. The resulting scale was termed *knowledge about scientific methods.* We also computed an overall test score for domain-specific knowledge, in which we added all items of the domain-specific knowledge test, establishing an *overall domain-specific knowledge* measure. The same content-specific knowledge test was also used to assess the learners' prior knowledge. For knowledge about mechanisms the used scale failed to reach sufficient reliability. Therefore, the pretest measure of knowledge about scientific methods was not included in our analyses. Reliabilities of the other measures ranged between .53 and .66 (Cronbach's α).

For the analysis of *processes of collaborative collaborative argumentation*, discourses of the dyads were transcribed and analyzed with a coding scheme aiming to identify arguments and argumentative sequences. Utterances were coded as arguments when they were content-related and when they included at least a *claim* that was made by the speaker. It was accounted for the fact that arguments can develop over time, i.e. arguments are not limited to single turns. Arguments were rated concerning what structural component they included. An argument was rated as containing *data* when it included an observation to make a claim. This observation could both have its origin in the contents of the learning environment and in the learners' prior knowledge. An argument was rated as including a *reason* when it was clear that the speaker aimed to say why (a piece of) data supported the claim of the argument. Further, each argument was rated with respect to the function it had for the context of argumentation. An argument was rated as *argument*, when it marked the beginning of a new topic that had not been discussed before. A *counterargument* was rated when it represented a reply to an argument that still dealt with the same topic and that went beyond a mere confirmation or negation of the argument. An argument was rated as an *integrative reply* when it contained both components of the argument and the counterargument that were uttered before. Thereby, it did not matter, which components of the integrative argument was taken from what earlier argument. In the context of this paper, we focus on how discourse develops when internal scripts are either high or low structured and the external script is low structured.

Statistical analyses. Concerning both domain-general knowledge on argumentation and domain-specific knowledge, we computed ANCOVA's with internal and external scripts as fixed factors and the scores in the specific outcome measures as dependent variables to test the two hypotheses. To determine the effects of internal and external scripts on domain-specific knowledge, the each specific domain-specific prior knowledge measures were included as covariates (except for knowledge about mechanisms because of its low reliability). Learners in the four conditions did not differ significantly concerning their domain-specific prior knowledge ($F(1,95) < 1.06$; *n.s.*). As a covariate for domain-general knowledge on argumentation, the point score in the test for assessing the internal scripts was used. For all analyses, the α -level was set to 5 %.

RESULTS

Acquisition of domain-general knowledge on argumentation

For *domain-general knowledge about argumentation*, learners with the combination of high structured internal and high structured external scripts received the highest scores ($M = 9.67$, $SD = 2.46$), followed by the "low structured internal/high structured external script" condition ($M = 8.00$; $SD = 2.67$). Next was "high structured internal/low structured external" ($M = 7.46$; $SD = 2.12$), followed by "low structured internal/low structured external" ($M = 6.76$; $SD = 2.17$). The main effect for the external collaboration script ($F(1,93) = 12.96$; $p < .01$) was significant indicating that the high structured external script led learners to acquire more domain-general knowledge about argumentation than the low structured external script.

Acquisition of domain-specific knowledge

Table 1 presents the mean scores in the domain-specific knowledge tests for each experimental condition. On the *overall measure* of domain-specific knowledge, learners holding high structured internal scripts reached higher scores than learners holding low structured internal scripts, especially when they collaborated by aid of the high structured external script. The group with the lowest scores in the overall measure of domain-specific knowledge was the "low structured internal/low structured external" group. An ANCOVA revealed a significant main effect for the internal script ($F(1,93) = 10.33$; $p < .05$), favoring high structured internal scripts.

Table 1: Mean scores (standard deviations in parantheses) in the domain-specific knowledge tests (pre- and posttests) in the four experimental conditions.

	Low structured internal script				High structured internal script			
	Low structured external script		High structured external script		Low structured external script		High structured external script	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
	M *(SD)*	M *(SD)*	M *(SD)*	M *(SD)*	M *(SD)*	M *(SD)*	M *(SD)*	M *(SD)*
Domain-specific knowledge (overall)	2.58 *(1.33)*	4.69 *(2.05)*	2.32 *(1.32)*	4.91 *(2.02)*	2.50 *(1.48)*	6.00 *(1.65)*	2.50 *(1.32)*	6.12 *(2.03)*
Knowledge about mechanisms	0.42 *(0.58)*	1.77 *(1.34)*	0.64 *(0.73)*	2.14 *(1.46)*	0.58 *(0.70)*	2.31 *(1.62)*	0.63 *(0.88)*	2.83 *(1.49)*
Knowledge about research methods	2.15 *(1.19)*	2.46 *(1.07)*	1.73 *(0.88)*	2.18 *(1.01)*	1.92 *(1.09)*	2.77 *(0.82)*	1.92 *(0.93)*	2.33 *(0.76)*

The same pattern could be observed for *knowledge about mechanisms*. Learners with high structured internal scripts outperformed learners with low structured internal scripts. The most successful group was "high structured internal/high structured external", followed by "high structured internal/low structured external, "low structured internal/high structured external" and "low structured internal/low structured external". An ANOVA yielded a significant effect for the internal script indicating that learners holding high structured internal scripts received significantly higher scores than learners with low structured internal scripts ($F(1,93) = 4.24$; $p < .05$).

For *knowledge about scientific methods*, a different and rather surprising pattern occurred. There, learners holding high structured internal scripts who had collaborated on the basis of the low structured external script reached the highest scores, followed by learners with low structured internal scripts who were provided with the low structured external script. Learners with high structured internal scripts who collaborated on the basis of the high structured external script reached lower scores, but even lower were the scores for learners with low structured internal scripts who worked with the high structured external script. An ANCOVA revealed a marginally significant main effect for the external script ($F(1,93) = 3.18$; $p = .08$) indicating that learners who had worked with the low structured external script acquired more knowledge about scientific methods than learners having been supported by the high structured external script. Post hoc t-tests revealed that learners holding high structured internal scripts who had collaborated on the basis of the low structured external script were significantly better than both groups of learners having collaborated with the high structured external script ($t(70) = 2.42$; $p < .05$).

Processes of collaborative argumentation – examples from two dyads

In order to illustrate how internal scripts unfold in collaborative argumentation, we conducted a qualitative process analysis. The objective of this analysis is to identifiy single arguments as well as argumentative sequences and to assess their completeness in terms of the structural model proposed by Toulmin (1958) and the dynamical model by Leitão (2000). I.e., we were interested in what components single arguments include (data, claim, reason) and what types of arguments were parts of argumentative sequences (argument, counterargument, integrative argument). Below, we present excerpts from the written transcripts of two dyads. Partners of dyad 1

(Christina and Anne) were identified as holding low structured internal scripts, and the internal scripts of the individuals in dyad 2 (Svenja and Lea) were classified as high structured.

It was observed that collaborative argumentation processes of dyad 1 (Christina and Anne; low structured internal scripts), were deficient both with respect to the structural components of single arguments and the sequences of arguments. Christina and Anna rarely generated arguments that contained data, claims, and reasons, and almost never were able to complete an argumentative sequence consisting of an argument, a counterargument, and an integrative argument. The transcript in table 2 illustrates that Christina in turn 3 states a claim saying that the chemical substance is causing the frog deformities. After that, she fails to bring in data, and the reason she gives is rather poor in that it does not go beyond “that is somehow more logical” (turn 5). Her second claim in the second part of turn 5 (“No, earlier I would have said it’s the parasites for sure”) lacks a reason as well as scientific data that support the claim that parasites are causing the frog deformities. Christina and Anne also fail to create a longer argumentative sequence, although Anne is explicitly stating that she could find reasons for both hypotheses. She suddenly stops talking while starting to develop a counterargument, and Christina (turn 6) does not take up the chance to create a counterargument on one of the two arguments Anne stated before.

Table 2: Excerpt of a discourse of a dyad in the “low structured internal/low structured external” condition.

1. Christina: “Well, I think…”
2. Anne: “Yes?”
3. Christina: “that, well, the chemical substances, that they uhm mainly are responsible for it, because they did not find out a lot about the parasites yet. And, well, that is somehow…”
4. Anne: (interrupts) “Did we really say that?”
5. Christina: (continues) “…more logical after I have read all that stuff. No, earlier I would have said it’s the parasites for sure, but the… the biological stuff… that…” (stops talking)
6. Anne: “OK, so we are done then. Click it away.”
7. Christina: “What?”
8. Anne: “That site.”
9. Christina: “No!”
10. Anne: “Yes!”
11. Christina: “OK.” (clicks on an another site)

In the case of dyad 2 (Svenja and Lea; see table 3), collaborative argumentation was qualitatively better both with respect to the structural components of single arguments and the argumentation sequences that could be observed. Svenja and Lea often formulated arguments that contained data, claims, and reasons, and they also showed attempts to generate longer argumentative sequences. In turns 2 and 3, Svenja and Lea collaboratively construct an argument that contains a claim made by Lea (turn 2) and a reason by Svenja (turn 3). In turn 8, Lea adds data to the argument, which Svenja in turn 9 even extends. With respect to argumentative sequences, Svenja is concerned about possible counterarguments to their joint argument (turn 5, first part) but finds again some counterevidence against this possible counterargument (turn 5, second part). However, the two girls do not manage to create an integration of the two conflicting hypothesis in this excerpt.

Table 3: Excerpt of a discourse of a dyad in the “high structured internal/low structured external” condition.

1. Svenja: “So, what do you think is more likely? Chemical or parasite?”
2. Lea: “Well, what do we think? Well, I on my part think that chemical is more likely.”
3. Svenja; “Yes, I agree. Because, although the parasite can also attack them (the frogs) but not that strongly. And it can also not block it.”
4. Lea: “And also there is… I write it down, ok? (starts typing: “We think that the chemical hypothesis…”
5. Svenja: (interrupts) “Well, but they did block something that one time [inaudible]. But when their heads are shrinked…” […]
6. Lea: (continues typing: “…is more logical”) Is more logical, ok? Because…
7. Svenja: “Why do we think so?”
8. Lea: “Firstly it has been growing over the last years a lot, and the chemical stuff has become more, too.”
9. Svenja: “Secondly, they also said somewhere that the parasite just can block a part, didn’t they?”
10. Lea: “Yeah.”
11. Svenja: “Yes, where did we read that?”
12. Lea: “It was somewhere up there (points to screen). That’s where they said it. How should I write it?”

DISCUSSION

In this study, we investigated how differently structured internal scripts on collaborative argumentation play together with differently structured external scripts aiming at facilitating collaborative argumentation in a web-based collaborative inquiry learning environment. With respect to both processes and outcomes of collaborative argumentation, we set up two competing hypotheses, an interactive effects hypothesis and an additive effects hypothesis. In general, the results rather support the additive effects hypothesis: At least for the acquisition of *domain-general knowledge about argumentation* it was shown that the high structured external script supported all learners independently from their internal scripts. It appears that high structured external scripts (O'Donnell, 1999) can be designed to help even learners with high structured internal scripts on collaborative argumentation to acquire domain-general knowledge about argumentation. However, contrasting our expectations, the high structured external script did not support the acquisition of domain-specific content knowledge beyond the level that was reached by providing learners with the low structured external script. Concerning both the *overall domain-specific knowledge* and *knowledge about mechanisms*, learners with high structured internal scripts on collaborative argumentation acquired more knowledge about the contents of the learning environment than did learners with low structured internal scripts, regardless if they collaborated by aid of the high or the low structured external script. Thus, argumentation competences can be regarded not only as a goal, but also as a precondition for successful learning in web-based collaborative inquiry learning environments. It appears that when learners already hold higher-level procedural knowledge about argumentation, they can use this knowledge for a deeper elaboration of domain-specific information, thereby acquiring more knowledge. Since learners' internal scripts that guide them in collaborative argumentation can be assumed as having developed over long periods of time by being exposed to argumentative situations over and over again (Schank & Abelson, 1977), it can be argued that learners can use these scripts effortlessly just like a very familiar tool when they perceive themselves as participating in a collaborative argumentation situation. On the other hand, this stability of learners' internal scripts can make it difficult to influence them by the provision of a high structured external script.

However, the question why the high structured external collaboration script did not lead to the acquisition of more domain-specific knowledge deserves further consideration, especially since it even tended to undermine the acquisition of *knowledge about scientific methods*. It is possible that the design of the high structured external script was too much oriented towards inducing specific argumentative moves and that learners were already strongly challenged by following the script instructions so that they were not able to turn the support they received into deep elaborations of the learning material ("over-scripting"; Dillenbourg, 2002). Wanting learners to acquire both domain-general knowledge about argumentation and domain-specific knowledge might be too much to achieve at a time. Maybe the effects of an internalization of the argumentative knowledge inherent in the high structured script would only play out later in a new argumentative situation. This hypothesis will be subject to further research.

It is useful to take a closer look at the learners' talk during the collaborative learning phase. In the presented excerpts, we were able to identify internal scripts on collaborative argumentation "on-line" and observed that they do have effects on collaborative argumentation processes. High structured internal scripts are likely to lead learners to give more complete arguments (data, claim, reason; Toulmin, 1958) and at least to create counterarguments (Leitão, 2000). Learners with high structured internal scripts also seem to be more concerned about backing their arguments up with data and to challenge their own arguments even when both partners actually share a position. In low structured internal script groups it is evident that learners fail to formulate arguments containing data, claims, and reasons, and that obvious conflicts do not become subject of discussion, resulting in a rare construction of counterarguments. This should be validated in further studies and analyses. It is an interesting question if the additivity effect that was found for the acquisition of domain-general knowledge about argumentation will mirror with the results found on the process level.

Finally, it should be noted that generalizations concerning the nature of the interplay of high vs. low structured internal and external scripts should be drawn with caution, because of two reasons. First, subjects in this study generally reached rather low scores in the internal scripts test. This is not mysterious taking the rather bad results of German students from international comparison studies like PISA (Deutsches PISA-Konsortium, 2001) into account. Yet it might be that for learners with very high structured internal scripts (which apparently were not part of this study's sample) the interactive effects hypothesis might be supported, meaning that such learners would benefit much more from a low structured external script than was observed in this study because they can make extensive use of the degrees of freedom they are provided with by the open structure of the external script. Second, it is unclear to what extent internal scripts on collaborative argumentation can be considered domain-general or have to be conceptualized as varying between contexts. Further research is needed to address this issue.

On a theoretical level, we believe that the study can contribute to the development of a framework for describing the impact of internal and external scripts for collaborative learning. Thereby, a distributed cognition perspective (e.g., Perkins, 1993) might be a valuable frame of reference. From this perspective, it is an important question how to orchestrate the different scripts in a way that they promote effective learning. Taking a systemic approach, it is assumed that learners and their (social, artifactual, and also instructional) surround make up a learning system, in which learning is or can be guided by different system components, namely the individual learner, his or her learning partner, the computer-environment and the imposed external script. Since it is likely to assume that individuals will internalize parts of the external script, the resulting framework would also have to account for states of transition of script components from the external to the internal. These internalization processes are then again important with respect to how instruction (i.e., external scripts) should be designed to account for changes in the learners' internal scripts. According to Pea (2004), we urgently need methods to continuously assess the learners' actual state of knowledge, which in turn must inform the degree of fading the external script instructions out.

From a practical perspective, the merit of this study is that it demonstrates that in problem oriented, collaborative learning environments, external scripts should be used whenever internal scripts are not available resp. if argumentation skills of learners can be considered as rather low. With respect to the outcomes of collaborative argumentative knowledge construction, the study even provided evidence that also learners with better argumentation skills are not hampered by providing them with a high structured external script. Web-based collaborative inquiry environments can be made more effective by implementing a high structured external script that scaffolds processes of collaborative argumentation. However, taking process analyses into account, it was demonstrated that learners with low structured internal scripts might have problems in rather open inquiry learning environments that contain only little information concerning how learners should argue with theories and evidence. For learners with high structured internal scripts, in contrast, this open approach to inquiry learning might be suitable.

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A Cognitive Tool in Handheld Devices for Collaborative Learning: Comprehending Procedural Knowledge of the Addition of Common Fractions

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Abstract. The aim of this research is to design a scenario for collaborative learning using a handheld or mobile device to aid the comprehension of new procedural knowledge. A cognitive tool (CT) – the graphical partitioning model (GPM) – that aids the development of the procedural knowledge needed to add fractions with unlike denominators was established from the results of a series of experimental studies. This paper discusses the redesign of the CT for use in handheld or mobile devices. The key to mediating the generation of procedural knowledge of the addition of fractions with unlike denominators is the process of searching for common denominators in the GPM. A scenario for collaborative learning is depicted, and the distribution of the cognitive load of learners across the GPM and their collaborative learning partners is elaborated. Three essential structures that promote collaborative work are discussed, namely, task structure, incentive structure, and group motivation.

Keywords: cognitive tool, collaborative learning, common fraction, handheld/mobile devices.

INTRODUCTION

Cooperative learning promotes self-directed and active learning through group interaction on interdependent tasks (Johnson & Johnson, 1999). It has the potential to promote lifelong learning skills, such as critical enquiry, reflection, and communication capabilities, that are not as readily attained by other means. We attempt to explore the pedagogy of deep learning through cooperative learning of the subject matter in this study, which is the addition and subtraction of fractions. This topic was selected because learners seldom understand the procedural knowledge that is associated such operations (Lamon, 2001; Pitkethly & Hunting, 1996), and there is a need to overcome the separation of knowledge from meaning that occurs in classroom instruction. The goal of cognitive technology is to develop cognitive tools (CT) that work naturally for human users and meet their needs (Janney, 1999). We adopt the view that CTs are both mental and computational devices that can support, guide, and mediate the cognitive processes of learners (Kommers, Jonassen & Mayes, 1992). The aim of this research is thus to devise a computational CT to help learners to comprehend new procedural knowledge in a collaborative learning environment.

A COGNITIVE TOOL FOR COMPREHENDING THE ADDITION OF FRACTIONS

Procedural knowledge is the knowledge that guides the performance of a task without providing the knowledge that underlies the performance. The procedural knowledge that we are interested in teaching in this study is the addition of fractions with unlike denominators. Traditional classroom teaching adopts the algorithmic approach, which has the disadvantage of separating knowledge from meaning. We aim to design a CT that assists learners to generate this new procedural knowledge. The CT to support the generation of procedural knowledge of the addition of fractions originated from a Cognitive Task Analysis (CTA) of the domain. We formulated an initial prototype from the CTA and defined a model of affordances from a case study evaluation (Kong & Kwok, 2002a, Kong & Kwok, 2002b). Figures 1 and 2 show the scaffolding support of the CT. The graphical partitioning model (GPM), which is a rectangular bar with partitioning capability, was designed as the mechanism that provides the learning support. The pedagogical benefit of the GPM is that it reveals the procedural structure for evaluating fraction expressions. It links the concrete manipulations of the partitioning of the fraction bars to search for a common fractional unit with the meaning of finding a common denominator.

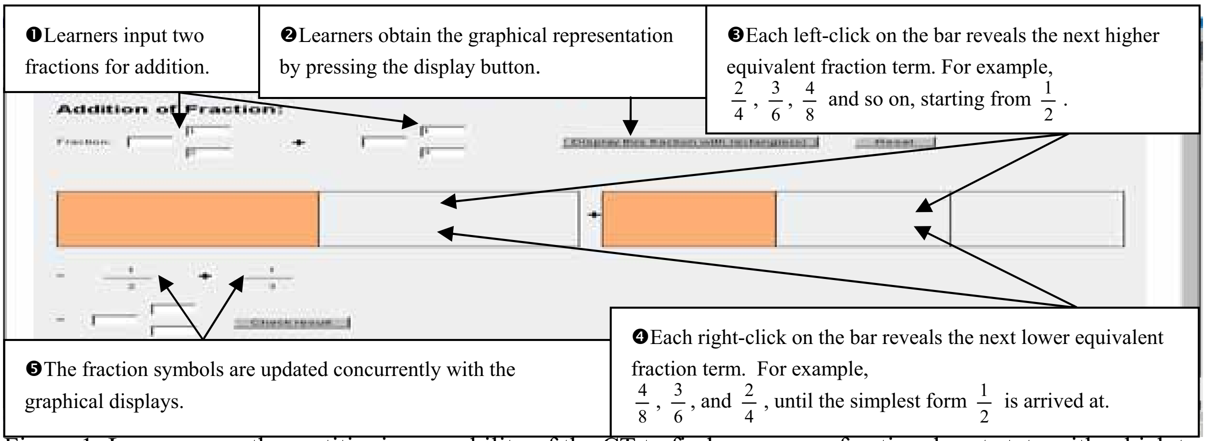

Figure 1: Learners use the partitioning capability of the CT to find a common fractional part state with which to carry out the addition process

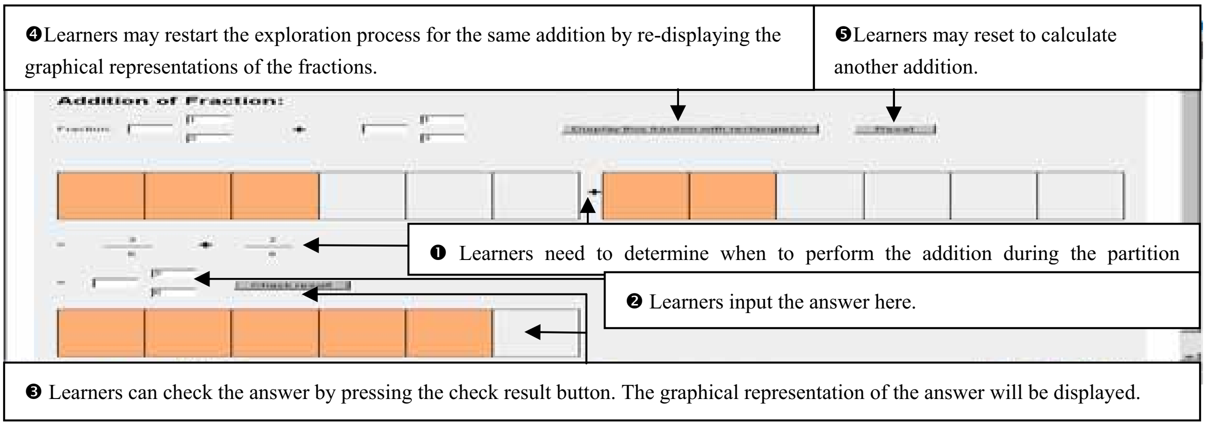

Figure 2: CT for developing the concept of requiring a common fractional part for the addition of fractions with unlike denominators

A series of experimental studies was conducted to test the effectiveness of the CT in helping students to learn about the addition and subtraction of fractions with unlike denominators (Kong & Kwok, 2002a; Kong & Kwok, 2002b Kong & Kwok, 2003, Kong & Kwok, in press). These studies explored the potential of the CT, and validated the effectiveness of the dynamic graphical model through evaluation studies. Figure 3 shows the improved hypothesis-testing interface of the GPM, which promotes reflection on the procedural knowledge that is needed for the addition of fractions with unlike denominators.

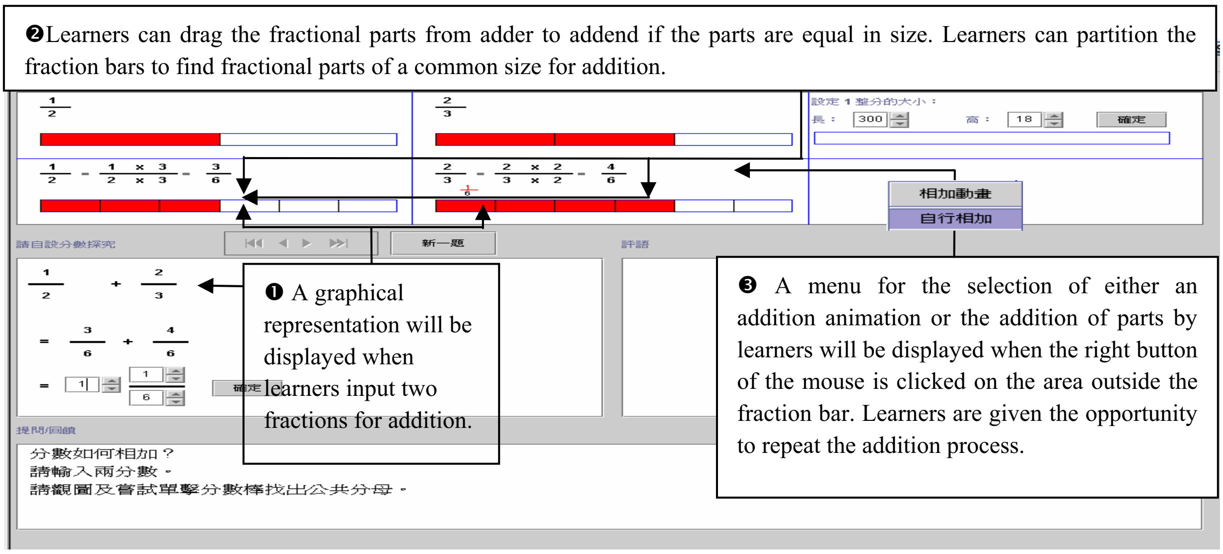

Figure 3: The GPM as hypothesis-testing bed for reflection on procedural knowledge of the addition of fractions with unlike denominators

The effectiveness of the enhanced CT was then further validated in a quasi-experimental pre-test-post-test control group study (Kong & Kwok, 2003, Kong & Kwok, in press). The results of the evaluation study indicated that procedural knowledge of the addition and subtraction of fractions with unlike denominators would indeed be generated in learners who worked with the CT if the knowledge of fraction equivalence were developed from a conceptual understanding of its meaning.

AIM AND OBJECTIVES OF THE STUDY

Scaffolding refers to the focused support that is offered to learners to help them to accomplish tasks, and especially difficult tasks, at critical times. We developed the CT for learning about the addition of fractions with unlike denominators by first assessing the learning difficulties of learners, and then designing the necessary scaffolding to support them. As handheld devices and mobile technologies are readily available nowadays, we saw the potential for developing the GPM as a collaborative learning tool for use with such devices, and thus decided to redesign the CT accordingly. Pervasive learning is a new way of using mobile and wireless devices to facilitate learning everywhere. In this study, we take pervasive learning to mean learning anywhere within a classroom. Pervasive learning through handheld devices and wireless technology provides a new dimension of mobility and connectivity, which increases communication between students and teachers, allows for a new type of collaborative learning experience, and, more importantly, increases the motivation of learners to participate actively in the learning process. We wanted to develop a pervasive learning environment to promote learning by reflection through collaborative learning in a physical-affordance environment (Roschelle and Pea, 2002). Thus, the aim of the study is to address the problem of redesigning the CT to facilitate collaborative learning. There are two objectives: to redesign the CT for handheld devices, and to add new functions to the CT to facilitate collaborative learning.

A COGNITIVE TOOL FOR COLLABORATIVE LEARNING

We needed to address two main issues in redesigning the CT for collaborative learning in handheld devices: the human-computer interface and the communication model between students and teachers. In designing the human-computer interface, we needed to preserve the original features of the CT, but also provide a new interface to facilitate collaborative learning and to allow for the constraints and limitations of handheld devices. Figure 4 shows the interface of the redesigned CT in handheld devices for paired collaborative learning.

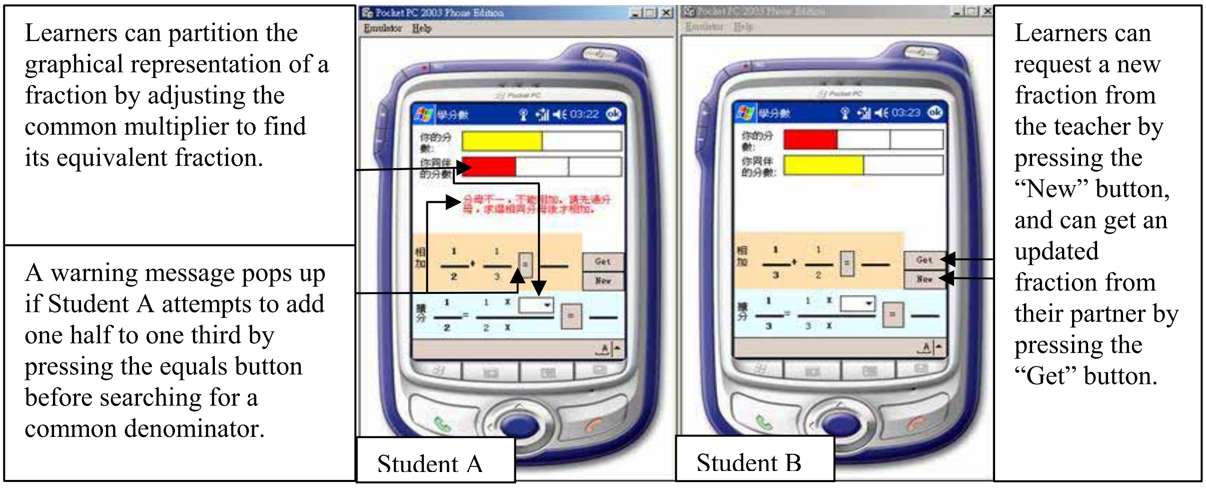

Figure 4: The interface of the redesigned CT in a handheld device for paired collaborative learning

The original GPM of the CT was preserved in the redesigned version, in that learners can still partition the graphical representation of a fraction by adjusting the common multiplier to find its equivalent fraction. However, two new features to aid communication between students and teachers were added: the Get and New functions. Learners can request a new fraction from the teacher by pressing the "New" button, and can get an updated fraction from their partner by pressing the "Get" button. The key to mediating the generation of the necessary procedural knowledge is the process of searching for common denominators. Our pervasive collaborative learning environment allows learners to distribute their cognitive load to the handheld device and to their learning partner during the search process. However, for this to work, there is a need to encourage genuine collaboration. There are three important factors in the promotion of cooperative behavior: task structure, incentive structure, and group motivation (Slavin, 1980). To promote cooperative behavior, the task structure, incentive structure, and group motivation must be designed so that the group member are mutually dependent (Sharan & Shaulov, 1990). In this section, we discuss the design of a pervasive collaborative learning environment in the classroom to aid the comprehension of the procedural knowledge through cooperative behavior.

Task Structure

The basic task that must be collaborated on is to evaluate a common fraction expression that has unlike denominators. Fraction expressions with two common fractions are generated by the computer system. All of the learners in the class are assigned to work in pairs by the teacher, and each pair of learners is assigned a fraction expression to evaluate. However, each learner receives only one half of the pair of fractions in the expression, and has to obtain a "New" fraction from the computer system for each task. Each learner then has to "Get" an updated version of the other fraction from their partner to start and continue the addition. Figure 4 shows that both learners have obtained a new fraction to add and a fraction from their counterpart to start the addition process, and that Student A has attempted to add one half to one third by pressing the equals button before searching for a common denominator. A warning message pops up and advices the student to search for a common denominator before undertaking the addition.

To accomplish this task, the learner must therefore determine an equivalent fraction to the fraction that is initially given to attain a pair of common denominators with their learning partner. This task requires cooperation between the learners in a pair. The rule that guarantees collaboration is that a learner has no right to change the equivalent state of the common fraction of their partner. In summary, the design of this task has three implications for the promotion of collaboration. Firstly, learners must cooperate before they can successfully add together two fractions with unlike denominators. Secondly, learners have to communicate and learn how to improve the efficiency of the search for a common denominator, which means that they have to reach a consensus with their partner to obtain the lowest common denominator. Thirdly, learners may seek to understand the procedure by discussing the graphical meaning of the search for the common denominator with their partner. Figure 5 shows Students A and B attempting to find equivalent fractions in the search for a common denominator.

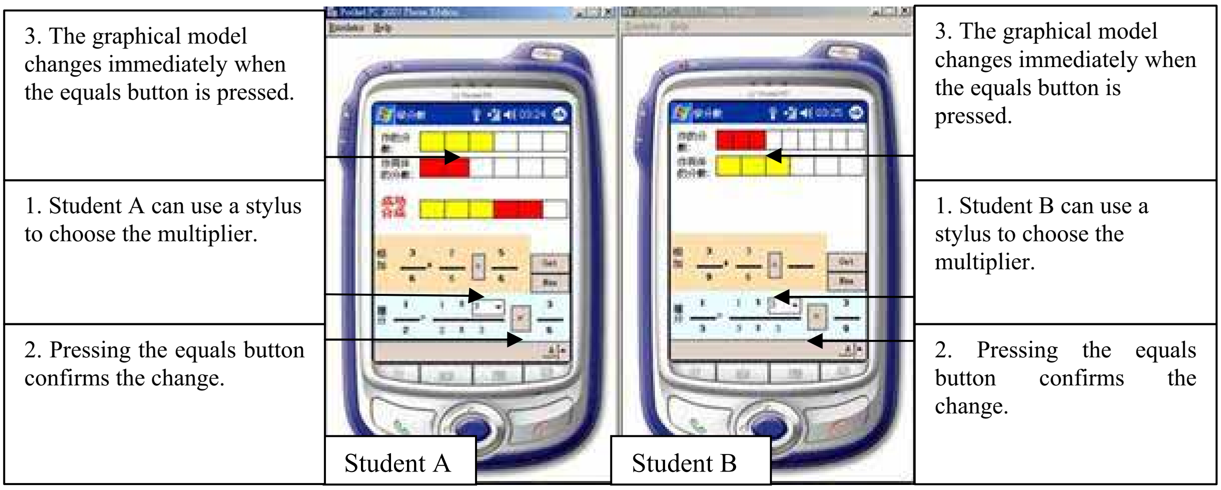

Figure 5: Students A and B attempt to find equivalent fractions in the search for a common denominator

Incentive Structure

According to Slavin (1980), incentive structure and group motivation are as important as task structure in the promotion of collaborative learning. A common practice in the assessment of performance in group work is to assign the same score to each individual learner in the group. However, this structure of assessment does not provide the individual with the incentive to contribute to the learning process, because learners obtain the same result regardless of how much effort they put in. Therefore, an incentive structure that encourages individual effort was attempted in this study. The computer checks the time that each individual takes to accomplish the task. Figure 5 shows that Student A has successfully found the common denominator for the addition, but that Student B is still searching for it. In this instance, Student A will get a higher score than Student B. The performances of learners with greater ability will thus be reflected by a shorter task accomplishment time.

Group Motivation

A teacher can define the tasks as group work, so that learners have to complete the addition tasks as a requirement for the completion of the entire task. This encourages group motivation in the learning process. In particular, group motivation can be achieved by organizing a competition between groups to complete as many of the addition tasks as possible in a given period of time. Giving awards will promote collaborative work and will provide more opportunity for learners to carry out reciprocal tutoring, which in turn will help them to better comprehend the meaning of the task. Therefore, in addition to the task and incentive structures, group motivation tactics should also be considered to motivate learners to work as a group. This is particularly applicable at the consolidation stage of the learning process.

CONCLUSIONS

In this study, we designed a collaborative learning environment using a CT for handheld or mobile devices that aids the comprehension of new procedural knowledge. A scenario for collaborative learning is depicted, and methods for distributing the cognitive load of learners across the graphical partitioning model and their collaborative learning partners are elaborated. Because the key to mediating the generation of procedural knowledge for the addition of fractions with unlike denominators is the process of searching for common denominators, the graphical partitioning model allows learners to comprehend the meaning through graphical representations. Some learners may gain this meaning through individual effort, but some learners may not be able to comprehend the meaning by themselves. Thus, three essential structures for the promotion of collaborative work – task structure, incentive structure, and group motivation – are designed and discussed. Learners in this collaborative learning environment will have more opportunity to learn from their partners, and thus more chance to comprehend the necessary procedural knowledge.

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Arguing on the Computer

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Abstract. We describe a collaborative computer-based activity as a means of developing argumentive discourse skills in middle-school students. The rationale for use of this technology is that it heightens the opportunity, and indeed demand, for metacognitive reflection on the communication, relative to direct verbal exchange. This demand is further heightened procedurally in two ways: (a) each dialog takes place among four participants, two who collaborate in producing and transmitting one side of the dialog and two who collaborate in producing and transmitting the other; subsequently, the respective pairs engage in analysis of a written transcript of it, with the aim of identifying how it might be improved.

Keywords: Argumentive discourse skills, metacognitive reflection

INTRODUCTION

Research on the development of inquiry and argument skills within developmental psychology remains largely unconnected to efforts within the CSCL community to use technology to scaffold these skills (Weinberger & Fischer, in press; Andriessen, Baker & Suthers, 2003; Hmelo-Silver, 2003). In describing our work to the CSCL community, we attempt here to forge such a connection. We describe a method and preliminary findings that have evolved from work with middle-school students aimed at developing intellectual skills through collaborative computer-based intervention (Kuhn, in press). The microgenetic method (Kuhn, 1995; Siegler, in press), in which close observation is undertaken of strategy changes as individuals engage repeatedly in the same or similar tasks over time, is employed as an analytic tool. Initial work was focused on the development of inquiry skills (Kuhn, 2001; Kuhn, Garcia-Mila, Zohar, and Andersen, 1995) and emphasized the ways in which social collaboration can provide intellectual scaffolding at the metacognitive, as well as cognitive, level. In other words, a collaborator monitors and manages cognitive strategies for a partner in a way that the partner is not yet able to do for him or herself. In a study by Andersen (reported by Kuhn, 2001), over a period of weeks students worked on parallel inquiry problems, one by themselves and the other with a partner, allowing direct comparison of performance and progress in the two conditions, and in a significant number of dyads the pair working together exhibited superior strategy use to what either member of the pair showed when working alone.

ARGUMENT VERSUS ARGUMENTATION

In current work we are examining collaborative computer-based activity as a means of developing intellectual skills of argument (Kuhn, in press). While inquiry has been embraced as a curriculum goal throughout the US science curriculum and to a large extent globally, argument by comparison has received relatively little attention as an intellectual skill. Yet educators seeking to develop thinking skills would likely consider their efforts largely successful if students became proficient in advancing, critiquing, and defending claims in reasoned discussion with peers. There exists a good deal of theoretical literature on argument and argumentation (see van Eemeren, Grootendorst, & Henkemans, 1996, for a sampling), but relatively little empirical evidence has been available regarding argument skills, despite their considerable educational, as well as theoretical, significance (Yeh, 2002).

The terms `argument` and `argumentation` reflect the two senses in which the term `argument` is used, as both product and process. An individual constructs an argument to support a claim. The dialogic process in which two or more people engage in debate of opposing claims can be referred to as `argumentation` or `argumentive discourse` to distinguish it from argument as product. Nonetheless, implicit in argument as product is the advancement of a claim in a framework of evidence and counterclaims that is characteristic of argumentive discourse, and the two kinds of argument are intricately related (Billig, 1987; Kuhn, 1991). Most of the empirical research on argument has been devoted to argument as product. Recently, however, this picture has begun to change, reflected in a landmark special issue of the journal Discourse Processes (Voss, 2001) that contains articles on argumentive discourse and its development.

MAKING ARGUMENTATION AUTHENTIC

In our own initial research on young adolescents' argumentive discourse (Felton and Kuhn, 2001; Kuhn & Udell, 2003; Felton, 2004), the weaknesses observed in dialogic argument in some ways resemble those observed in individual arguments, with only a minority of arguers going beyond exposition of their own position. Only infrequently do we see the genuine exchange that is the mark of authentic discourse. Why might this be? Felton and Kuhn (2001) suggest that attention to the other person's ideas and their merits may create cognitive overload, or it simply may not be recognized as part of the task. Most likely, both factors are at work – both procedural and meta-level limitations constrain performance.

As a result, dialogic argument is reduced to an activity curiously like that of individual argument. The objective is the same in both cases – to make the most compelling case possible as to the merits of one's position. If I do a good enough job, my position will prevail due to its merits, outshining any competitors, who will merely fade away. In the case of individual argument, the task is taken on as a solitary endeavor. In the case of dialogic argument, the task is similarly individual but two people engage in it simultaneously, juxtaposing their respective efforts in a turn-taking format.

A number of authors suggest that dialogic argument is the most viable and productive medium for developing students' argument skills (Billig, 1987; Kuhn, 1991; Graff, 2003). When asked in expository writing to generate an argument in support of a claim, too often, Graff (2003) suggests, a student undertakes to do so with little or no sense of why anyone might want to claim otherwise. In the absence of a physically present interlocutor, he goes on to propose, the student takes the task to be one of stringing together a sequence of true statements, avoiding the complication of stating anything that might not be true. The result is often a communication in which both reader and writer, or audience and speaker, are left uncertain as to why the argument needs to be made at all.

An implication of these ideas is that students stand to develop stronger argument skills in the dialogic context of argumentive discourse than they do in producing their own individual arguments in support of a claim. This is one of two key hypotheses addressed by our research. Its rationale is twofold. Dialogic argument lies at the heart of all argument, as noted. In addition, and quite unlike expository argument, dialogic argument has the advantage of building on the familiar form of everyday conversational exchange.

Teachers may claim that their students have ample opportunities for dialogic argument in the context of classroom discussions. Teachers conducting such discussions, however, commonly make one of two mistakes. One of them is to allow the activity to relapse into nothing but consecutive self-expression, first on the part of one student, then another. It does not matter much what each student says, and no student need listen to another. In this worst-case scenario, the only attention the next student pays to the speaker is to wait to observe a signal that this speaker is about to finish, so that he or she can begin. As long as everyone gets their share of turns to speak and no one speaks too long, there is a wealth of opportunity for self-expression. Yet, no further purpose is fulfilled. There is no continuity, no direction, no sequence to the discussion. Nor is there any particular role for the teacher to play except the procedural one of ensuring that the turn-taking norms are followed.

The other mistake teachers make is to retain tight control of the activity so as to insure that the content of what is said meets the teacher's concept of what needs to be covered. The teacher calls on students successively, and if a student begins to veer off track, the teacher will steer him or her back, if necessary with a more specific question ("Let me ask you this"). Or the teacher may simply go on to another student – a tactic even the best teachers are guilty of – until some student gives the response the teacher is seeking.

In both the self-expression and teacher-controlled discussion modes, the same model of communication prevails. All talk is directed to the teacher (figure 1). The most the student can hope for in the way of response is approval from the teacher for what he or she has said, before it becomes another student's turn to speak. Whether or not the teacher communicates it explicitly to students, the teacher's own behavior models the norm that we must be respectful of another's ideas, and students are usually quick to pick it up. Hence, students rarely get any strong reactions to the statements they make in classroom discussion. Instead, typical is the response teachers so often rely on when they can think of nothing else, "That's an interesting idea, Jamie," before going on to another student.

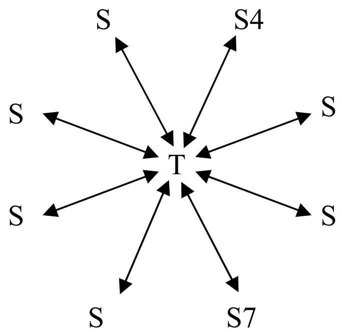


Figure 1: Teacher-centered Discourse

This form of communication stands in striking contrast to the discourse students will engage in as soon as they leave the classroom and enter the schoolyard. One student makes a claim, another challenges it, and others join in (figure 2); strict reciprocity between any pair of participants is not expected, but, still, a speaker addresses the claim that has just been made, with the goal of reaching a resolution. This discussion has a life that goes beyond the role of individual participants. If interest is not keen enough to maintain the discussion, it evolves to a new topic or terminates. Rarely do participants continue to talk `about` the topic without talking `to` one another within this goal-directed framework. It is this feature of authentic talk `to` one another that we seek to capture in students' dialogic arguments.

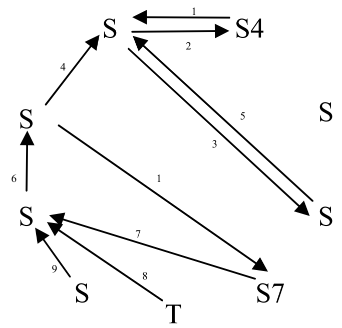


Figure 2: Student-centered Discourse (Hypothetical initial 10 moves)

COMPUTERS AS A MEDIUM FOR ARGUMENT

We thus have adopted dialog about a disputed claim as a template for the development of students' argument skills. The second key feature of our research is that this dialog take place via computer. The method takes advantage of the fact that the middle-school sample we have worked with have acquired everyday familiarity with email and instant messaging as a means of communication with peers and are comfortable with it. The rationale for use of this technology in the present context is that it will heighten the opportunity, and indeed demand, for metacognitive reflection on the communication (Kuhn, 2000, 2001), relative to direct verbal exchange. As elaborated below, this demand is heightened procedurally in two ways: (a) each dialog takes place among four participants, two who collaborate in producing and transmitting one side of the dialog and two who collaborate in producing and transmitting the other; subsequent to the electronic dialog, the respective pairs engage in analysis of a written transcript of it, with the aim of identifying how it might be improved.

In the work described here, 28 sixth-grade eleven- and twelve-year-old students were involved in an "Arguing on the Computer" intervention that took place over the course of 14 successive 45-minute class periods, twice per week. Students were introduced to the ColumbiaTown project, in which they were to debate what rules and laws ColumbiaTown should have. The first debate, they were told, was about whether ColumbiaTown children should go to the town school or whether it's all right for the parents to teach them at home if they want.

BACKGROUND OF THE DEBATE

"We're going to be working in this project on setting up a new town in an undeveloped area. There will be lots of things to decide. One important issue that has come up right away is school for children. A good school has been set up that the parents and children are happy with. All children attend through high school. Since the houses are far apart, school gives children a chance to be together.

A problem has come up. The Costa family has moved to the edge of town from far away Greece with their 11 year old son Nick. Nick was a good student and soccer player back home in Greece. Nick's parents have decided that in this new place, they want to keep Nick at home with them, and not have him ever be at the school with the other children. The family speaks only Greek, and they think Nick will do better if he sticks to his family's language, and doesn't try to learn English. They say they can teach him everything he needs at home.

What should happen? Is it okay for the Costa family to live in the town but keep Nick at home, or should they send their son to the town school like all the other families do?"

AN E-BASED ARGUMENT INTERVENTION FOR MIDDLE-SCHOOLERS

The intervention activity consists of the following phases:

1. Individual argument (Session 1)

Students' opinions and supporting arguments regarding the first topic are assessed individually using a paper-and-pencil instrument (appendix B).

2. Paired electronic arguments with opposing-view pair (sessions 2, 3, 4, 6, 8, 10)

Students are paired with a classmate who holds the same view (home okay or school mandatory); these two students collaborate in engaging in an e-dialog with another pair (in a different room) who holds the opposing view. Pairs are instructed and reminded to collaborate with one another in constructing their input and, once in agreement, to take turns typing it on the laptop the pair shares for the activity. Pairs engage a different opposing pair for each new dialog.

3. Reflective analysis of transcripts of previous e-arguments (sessions 5, 7, 9, 11).

After students have had the experience of several collaborative e-dialogs (sessions 2, 3, & 4), during session 5 they are presented the transcript of their previous e-dialog (session 4) and asked to reflect on it, using the "other-argument" scaffold sheet provided for them (see figure 3), which elicits the other pair's main argument and the counterargument they offered in their dialog and offers the opportunity to construct another, better argument. (Students' attention is thus focused directly on the other side's arguments, for those students who have not yet attended to them in the dialogs.) When all pairs have completed the sheet, sheets (and dialog transcripts) are exchanged with another pair, who then review their classmates' sheet and offer comments (in particular with respect to possible counterarguments.

During session 7, presented the transcript from session 6, students are offered the "own-argument" scaffold sheet (see figure 4). When all are complete, each sheet is passed to another pair who reviews it and offers suggestions (in particular with respect to possible "comebacks," i.e., rebuttals). During sessions 9 and 11, both sheets are available and students are encouraged to complete both.

4. Preparation for final, class-level e-argument

Session 12 marks the beginning of a culminating activity for students with respect to the topic. Students work within their same-side rooms, preparing for what will be a final "show down" debate at session 14. The pairs who have worked collaboratively to this point are now divided, one assigned to the other-side team and the other to the own-side team. Within each team, students' task is to focus either on other-side argument (and best counterarguments), in the case of the first team, or to focus on own-side arguments (and best comebacks to counterarguments) in the case of the second team. (Students thereby experience directly the dual functions of argument.) The teams use their laptops to collaboratively compile an e-folder containing a portfolio of the best own-side argument (and comebacks), for use in the showdown or (in the case of the other team) an e-folder containing a portfolio of likely other-side arguments (and best counterarguments). All previous scaffold sheets are available (as well as dialog transcripts) for students to consult if they wish. This activity is continued in session 13.

5. Execution of final class-level e-argument (Session 14).

In session 14, students in each room are divided into a red and a blue team of approximate equal skill (and equal numbers of own-side and other-side specialists from the preceding activity). The final debate is conducted as an e-dialog between the two classes, projected onto a Smartboard, with the red team presiding for the first half of the debate and the blue team for the second half. (Various other procedural rules govern the activity.)

6. Judging and feedback

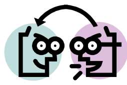
A transcript of the final debate is analyzed and an argument map prepared, diagramming all arguments, and all counterargument and rebuttals, on either side, that connect directly in the dialog flow to their corresponding arguments. A point system is then applied, to declare a winning team. The argument map and outcome is presented to all participants for their examination.

CONCLUSIONS

In sum, the present method incorporates successful elements of previous methods we have used in seeking to develop argument skills, a dyadic discourse element (Felton & Kuhn, 2001) and a goal-based element (Kuhn & Udell, 2003). In addition, and most significant, we have drawn on the availability of, and students' familiarity with, laptop computers to employ an electronic medium in which to situate discourse. This electronic medium, together with the socially collaborative context, we believe promotes the opportunity for reflection that scaffolds the development of meta-level cognitive skills. In stark contrast to the immediate response required in live discourse, electronic discourse enables one to contemplate both what one's conversational partner has said and what it is possible to say in response. A collaborative partner sharing the conversational role further heightens the demand for and likelihood of this reflection.

Our microgenetic analyses of dialog transcripts show rapid evolution in the quality of dialogs, as well as the quantity of discourse. The percentage of dialog devoted to off-task concerns rapidly diminishes as does the percentage devoted to meta-task utterances that are ineffective in furthering the argument. Such utterances, for example, progress from "You're being obnoxious" to "You're not giving a reason for your opinion." Our previous work applying a dialogic coding scheme (Felton & Kuhn, 2001; Kuhn & Udell, 2003) to dialog transcripts has shown the major developmental changes to occur in an increased usage of counterarguments and a decreased usage of statements explicating one's own position. A study by Felton (2004) documents that intervention involving metacognitive reflection enhances this process. Although analysis of data from the study described here is not complete, these same trends are evident. In continuing work, it remains for us to establish that gains are not limited to intervention argument topics and are maintained over time. We are also investigating the extent to which continuing intervention of the sort described induces further gain beyond that observed in an initial intervention. Alternatively, we may observe an asymptote following an initial intervention. This question has important instructional implications. Still a further question that has important educational implications and warrants investigation is the extent to which the observed gains transfer to individual (non-dialogic) arguments students make either verbally or in their expository writing. We look forward to addressing all of these in future work.

Team members____
Date _________

Let's think… Starting with the other side's argument 

One of the **other side's** MAIN ARGUMENTS was:	Our COUNTERARGUMENT **against** their argument was:
____ ____ ____	____ ____ ____

Give a specific example of an improved, more effective COUNTERARGUMENT.

____

____

____

____

Figure 3: "Own argument" scaffold sheet

Team members____
Date ________________

Let's think…Starting with our argument 

One of the **our** MAIN ARGUMENTS was:	**Their** COUNTERARGUMENT against our argument was:	**Our** COMEBACK was:
___________________________ ___________________________ ___________________________ ___________________________	___________________________ ___________________________ ___________________________ ___________________________	___________________________ ___________________________ ___________________________ ___________________________

Give a specific example of an improved, more effective COMEBACK.

____

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Figure 4: "Other's argument" Scaffold Sheet

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A Lightweight Approach for Flexible Group Management in the Classroom

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Abstract. In this paper we describe a session management system for setting up various collaborative classroom scenarios. The approach is addressing the additional workload of administrating classroom networks on the teacher, which is an important aspect for teachers' willingness to implement technology enhanced learning in schools. The system facilitates preparation of classroom scenarios and the adhoc installation of networked collaborative sessions. We provided a graphical interface, which is usable for administration, monitoring, and for specification of a wide variety of different classroom situations with group work. The resulting graphical specifications are well suited to be re-used in the more formal learning design format IMS/LD; this is achieved by a automatable transformation of the scenarios to LD documents.

Keywords: Collaborative classroom scenarios, lightweight classroom orchestration, learning design, shared workspaces

INTRODUCTION

In the area of technology enhanced learning, the term "learning environment" (LE) is usually associated with a virtual or computational system that supports learning in a specific coherent way. There are domain orientated environments, sometimes called microworlds, which support specific semantic representations and processing mechanisms, but also general "learning platforms" that aim at organisational, communication and archiving support for learning communities. In spite of the differences between these concepts, neither one challenges the conventional assumption of the LE residing on one or more computers. In the European project NIMIS (1998-2000), we have tried to break with this understanding by identifying the LE with the classroom. In such a computer-integrated classroom (Baloian et al., 2002), a mixture of traditional (or natural) forms of communication and media may co-exist with digital media serving different functions which may be partly identical to traditional media use and in other parts actually qualitatively new. We have used the term "digital mimicry" to characterise interactive digital media functions which mimic traditional forms such as the use of a pen based big electronic display instead of a chalkboard (cf. Hoppe, 2004). Interactive simulations are a typical example of a genuine new media function which is bound to the digital modality. However, there is a general added value that we expect already experience from combining digitised traditional media (e.g. scanned-in paper notes) with digital mimicry applications and real new media into a new form of digital information flow with specific forms of recording, re-use, re-enactment and extension/modification.

In the more recent EU project SEED (2001-2004), we have tried to create classroom innovation using interactive media together with a group of teachers. These teachers were introduced to the new types of hardware and software (mainly annotation and modelling tools) and were invited and supported in appropriating these for their own teaching. This has led to interesting software extensions and blueprints for teaching in areas so diverse as biology, mathematics and language studies. The focus of these activities was clearly on representational tools, not so much on a general communication infrastructure. Indeed, we found that existing school intranets are still too poorly developed in terms of availability, maintenance and coherence to get the full added value out of the digital enrichment of the classroom in terms of organisational memory functions. Due to this lack of infrastructure, we have not been able to fully implement our concept of a computer-integrated classroom in the various schools we worked with. Yet, we have explored the general feasibility of using new devices such as low cost graphics tablets for hand writing as well as big interactive displays, tablet PCs as well as PDAs in domain specific applications with a special focus on collaborative use. Importantly, the specific applications were not predefined but designed and put into practice by the teachers. In almost all of these experiences, there was a general demand for setting up classroom networks with flexible grouping and archiving/recording mechanisms with an additional time effort being small enough to be justified for a 45 or 90 minute lesson. This gave rise to the implementation of an "ad hoc session manager" which has recently been finished and just undergone the first functional test.

There is an obvious similarity between this session manager and the idea "ad hoc networking" in learning scenarios with wireless and mobile devices. Chang, Sheu & Chan (2003) describe such an approach to setting up "ad hoc classrooms" with mobile devices, e.g in outdoor activities. This approach provides a standard set of communication functions (downloads, uploads, broadcasting etc.). Our goal is to facilitate more explicit and flexible structuring of the learning group based on the precondition of having a surrounding minimal school infrastructure with at least a pre-installed network in the classroom and potentially some stationary computers. Here, teachers are able to set up different collaborative scenarios with minimal effort. It turns out that the concrete scenario specifications can even be understood as a kind of explicit "educational modelling".

REQUIREMENTS FOR A FLEXIBLE CLASSROOM MANAGEMENT SYSTEM

Administrating computer based group work of a whole class means additional effort for the teacher. He has to subdivide the class into groups, each using several computers. He has to initiate the work with prepared material and distribute it to the students. In the following phase students work collaboratively on given topics, aware of the work progress of their group members. They share, merge, save, deliver and present their results. The teacher is interested not only in archiving the "final products" but in observing, supporting and protocolling the learning process of each group. Therefore he wants to "visit" the working sessions of his students.

From a requirements engineering perspective (Pohl 1993) we concentrate on the following functional requirements: Concerning the collaboration, the software has to facilitate a) grouping and rearranging of cooperation, b) synchronizing of common workspaces/learning places, c) monitoring, protocolling and archiving. Additionally d) presentation and e) (re-)use of results, i.e. the specified learning scenario as well as the results of the student work, are of high importance for the use in school. The diagram in figure 1 which illustrates the usage of our classroom management system includes use cases representing these functional requirements.

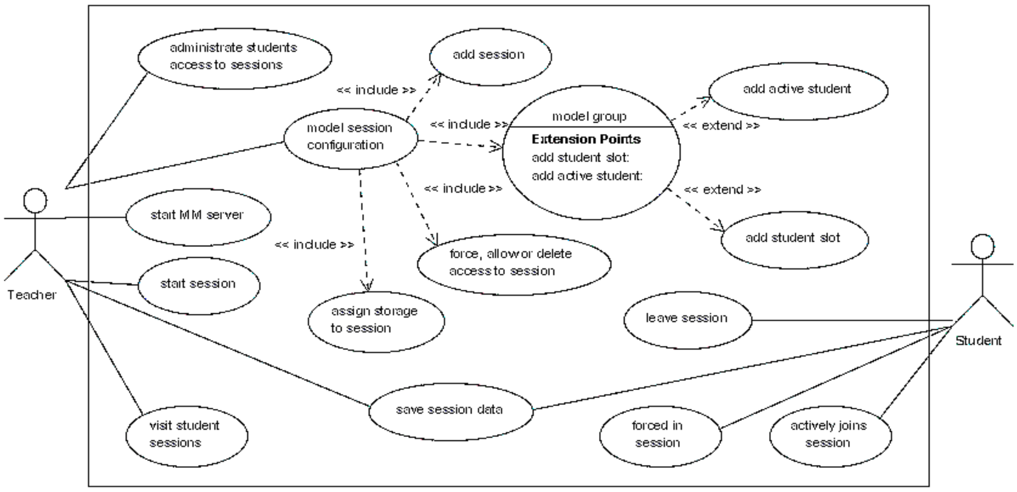

Fig. 1: Use case diagram: session managament for group work

Besides these functional features teachers will only accept a software tool if it fulfills other (non-functional) requirements concerning handling, performance, reliability and added value. Our software is designed to support the teacher in setting up computer based group work *ad hoc* and in preparing sophisticated forms of collaboration *in advance* and it *simplifies* to support, control, manage and rearrange the cooperation between the students and to access the produced data. This allows the teacher to use ICT in a new, different way increasing the benefit of group work, opening up possibilities to arrange cooperation among his students, to start and accompany learning processes, to integrate the results of the students in the current and following courses.

SYSTEM DESIGN AND IMPLEMENTATION

We implemented the proposed lightweight approach based on the mentioned requirements. Since we already use the collaborative modelling system Cool Modes (Pinkwart 2003) in school for mathematical modelling, computer science lessons and graphical argumentation (Harrer et al 2003) it was an obvious option for us to implement our system on this platform basis. In order to allow for synchronous collaboration among participants of a learning or modelling task, the Cool Modes environment is based on a framework that easily supports the extension of standalone Java applications to collaborative applications. This framework, called MatchMaker (Jansen, 2003) provides the possibility to share the inner data structures of Java applications and logging and replay functionalities to protocol additional information for the evaluation of collaborative work. It is important to stress that this functionality is not application dependent but provided by the framework that supports the collaboration. Therefore, these features are available with all applications that use this framework.

The Cool Modes framework was used with two different intentions in our scenario. On the one hand, it is used by the students to perform their collaborative modelling task, and on the other hand, the teacher used it in order to orchestrate the group work. Basically, a teacher could also model the groups with Cool Modes but use another, MatchMaker based tool, for the collaborative task.

On top of the Cool Modes platform we have developed a graph based visual language for the representation of the classroom networks. This visual language represents graphs with the following nodes and edges:

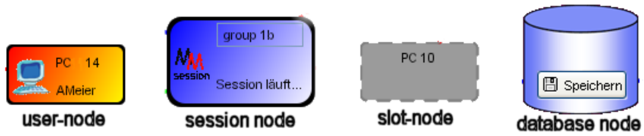

Figure 2: Elements of the visual language for modelling group work

The user-node represents a *client*. Visible information on this node are the name of the user or partners if students share one computer, the login name, the host he is working on and the IP address of the host. With the help of a *session node*, the teacher has the possibility to model and control (start/stop) sessions, see how many clients currently are connected with the session and the unique name of the session. A *database node* allows the teacher to store the data of a connected session at a previously defined place. This might e.g. be helpful for the teacher to collect the learning objects created by the students. Last but not least, the visual languages provides a fourth node, a *slot node* which acts as a wildcard for clients. Therefore, this node allows the teacher to orchestrate the different groups before the students enter the classroom and log into the system. Furthermore, this so-called *slot-node* could be filled with unique parameters of a certain user, like his login name. If such a unique parameter is provided with this node and the student who fits to this unique parameter logs into the system, he is automatically identified with this node and the node is replaced by the client node representing the student. If no unique parameter is provided, the teacher has to drag the client nodes to the slot nodes in order to make this matching. Basically, the slot-nodes are used by the teacher to model a collaborative learning design and those nodes do also provide the possibility of reusability.

Furthermore, the visual language provides three different edges in order to connect the different kinds of nodes. Basically, we have two edges that allow to connect a slot node or a client node to a session. On the one hand there is the *force-edge* which results in an automatic join of the client in the session and on the other hand we provide an *is-allowed-edge* in order to show a certain client is allowed to join a certain session. Another edge connects the database node with a session node in order to store the session data at the previously defined place.

One of the major goals for this approach was to ease teachers effort. He needs information about the computers that are available inside his classroom. Since the automatic detection is a non trivial task in the absence of a central server that can provide a naming and lookup service, we decided to use a multicast architecture to allow for flexible communication patterns. By this approach, each client only needs to provide two basic features on the multicast layer. On the one hand, the client must be able to receive multicast messages sent by the server to inform the client on which host the MatchMaker server is running, and on the other hand the client itself has to be able to send a multicast message around telling the server that there is a MatchMaker client available at a certain host. With the help of these multicast messages, the server can set up the topology of available MatchMaker clients, and the clients are informed where the server is located. Once the topology and the location of the server is communicated among the classroom network, the communication between the clients and the server is switched from multicast to Java RMI (remote method invocation). All of the higher level task, e.g. forcing a client into a session or getting the available sessions for a client, are then implemented on the RMI level.

DETAILED EXAMPLE AND FIRST EXPERIENCES OF USE

The group management tool was applied in a German secondary school in a computer science course of twenty 12 graders. The computer lab consisted of 15 + 1 networked computers. Our tool was not only used to administrate the group work but also to evaluate the work process and the results of different forms of group work. Each group work scenario can be classified by the degrees of freedom it offers students to structure their collaboration and their work on the task. Our ongoing research work will have a closer look on the influences of these two dimensions on the learning process of students and it outcomes.

In the described setting two different groups worked on a UML class diagram for a computer based monopoly game. Whereas the second group had the task in common the first one was divided into two subgroups with predefined division of labour. Additionally in this group one student acts as a coach to combine and present the merged parts. Figure 3 shows settings organization prepared in advance through the group management tool. The figure shows the two sessions for group 1 with four respectively two students. Another student acting as a coach *is allowed* to join both sessions of group 1 and the final presentation session. The other students are *forced* to join the session of group 2. These different modes are indicated by differently coloured edges.

In the first minutes the teacher controlled the group management while the students logged themselves on. Students not automatically assigned to their session by (their correct) log-in name where placed and linked by hand. After the teacher had initiated the group work a short introducing phase of 15 minutes started in which basic classes were defined collaboratively in both groups. These basic models the students elaborated in shared workspaces using a toolbox for UML class diagrams. The modelling work was done by the two subgroups of Group 1 (n = 9) following their distinct orders in a concentrated and goal-oriented style. Out of technical problems the coach was not able to do his mediating work and could not merge the partial models. Group 2 (n = 11) began in a more "anarchistic" way. After several minutes they used a new start to structure and distribute their work. Now they decided to use separate areas of the shared workspace to work on subtopics in informal subgroups. The teacher observed their work joining the sessions, saving versions of the growing models. Finally students presented the results by joining the presentation session used for visualisation with a data projector.

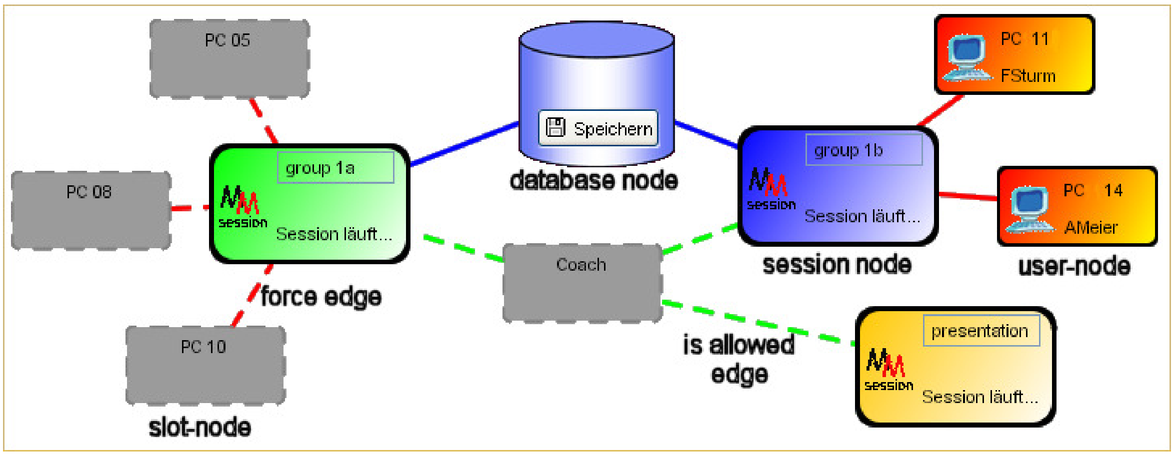

Fig. 3: Modell representing the arrangement of computer based group work

We observed that students of both groups were able to model relatively complex class diagrams in a short amount of time. They could cope with both arrangements very well, working effectively and competently. Using a questionnaire we found out, that the students were widely satisfied with their results (in a scale of 1 up to 5 both groups had an average value higher than 4) and with the collaboration (group 1: 90 %, group 2: 82 %). They enjoyed to work together directly and in a distributed manner on a common task, subsuming their own ideas without restricting each other. They were aware of the ongoing group work. Group 2 enjoyed the freedom to structure and distribute their work, communicating directly before modelling on the computers. In comparison to group 1, a qualitative difference is to be found concerning satisfaction and intensity of work. Whereas in group 1 all students had the feeling of having worked homogenously, in group 2 four students (36 %) pointed out that some had worked less than others, whereas 45 % where satisfied with the collaboration – these may be indications for unresolved conflicts during the negotiation.

LEARNING DESIGN BY EXAMPLE

The concrete collaborative scenarios created by the teacher have a high potential for further usage: they can be considered as templates of learning design that may be used for different forms of modelling. This can be done by abstracting concrete assignments of learners to role definitions. This is already prepared to a great extent in our system by providing the "slot nodes" as placeholders for concrete group participants.

The definition of learning designs attracted a lot of interest in the last years and resulted in proposals of educational modelling languages, such as ClassSync ML, EML and its successor IMS Learning Design (IMS/LD, IMS 2003) specified by the IMS Global Learning Consortium. The definition of learning designs for collaborative scenarios tends to be much more complex than the designs for individual learning, because different group situations and roles therein have to be specified. Related work, such as (Hernandez et al. 2004) showed that some aspects of complex collaborative designs (also called Collaborative Learning Patterns) are not represented properly in IMS/LD and extensions are necessary. In the light of this we think that the direct use of the XML-based IMS/LD format for specification by the teacher, who usually is not an expert in computer science specification, is a major challenge for the learning designer. This brought us to the idea to use the described tool also as an editor for collaborative learning designs using IMS/LD as output format. The teacher can then specify his learning design "*by example*" creating a concrete visual model, instead of using the machine-level textual format of IMS/LD. We defined a mapping from our scenarios to IMS/LD document :

1. Each session within the classroom scenario is mapped to an IMS/LD "learning-activity", in our example "1a", "1b", "presentation", using the session's textual description for title and description of the activity
2. Each client node or slot node is mapped to an IMS/LD role of type "imsld:learner", in our example "coach", "Fsturm". Since roles of a learning design are instantiated at runtime and thus instances cannot be specified in the document, the client nodes of CoolModes are also abstracted to roles.
3. The teacher who is implicitly present in the scenario (but not in the model) is represented in the learning design as a role of type "imsld:staff"
4. The whole classroom scenario graph of our visual language format is mapped to an IMS/LD "act"
5. For each learner (client or slot node) an IMS/LD "role-part" is created within the act with the respective "role-ref"; this role-part includes a "learning-activity-ref" to the respective learning activity (in our format a session node, see above) for each edge connecting the learner with the session node. In case of a "force edge" there is one session available as learning-activity-ref. The "role-part" for the teacher includes every learning-activity to show his potential participation in every session, in our example "coach" with role-part learning activity "1a", "1b", "presentation".

At the moment we only can define one-act scenarios directly using our MatchMaker/CoolModes environment. More complex learning designs with a sequence of acts are obviously a desirable target to enable richer classroom scenarios to be defined and conducted. We plan to extend our IMS/LD export so that we can combine multiple models in our system to a temporally ordered sequence of acts and thus a full-fledge learning design "play". The teacher just specifies the configurations separately and connects them with a specific sequencing. Even more convenient is "specifying by example" the whole learning process model by letting the system record her specification process over time. Multiple workspaces and a logging mechanism of the modelling process (Jansen 2003) are already available for our system and will be put to use for this "multiple act specification by example" in our next steps. The exported IMS/LD-format can easily be attributed with e.g. "learning objective" in a simple editor we have developed to enrich the design with more pedagogically oriented information.

CONCLUSION

Utilising technology enhanced classroom scenarios in school practice usually burdens the teacher with technical administrative effort in setting up the scenario. We addressed this challenge through a lightweight approach for flexibly setting up collaborative classroom sessions. Based on the requirements to reduce the teachers' effort we implemented a classroom management system that can be visually administrated without deep technological knowledge. The resulting visual models can be utilised by the teacher for the preparation of scenarios at home as well as for adhoc classroom setup. The visually specified scenarios are a step towards re-usable learning designs, which is supported in our architecture by a mapping of concrete scenarios to IMS/LD documents which could also be used for different classes, courses, or even other software platforms.

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Information and Communications Technology and Literacy Development

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Abstract. This paper reports an investigation of how students' literacy improved through on-line discourse. Two English literature classes in an inner city multicultural secondary school participated. The teacher taught both classes-an experimental and a control class. The experimental group was a class of Grade 9 students with access to the discourse space, Knowledge Forum®, for writing narrative and expository texts, critiquing others' texts, and exploring ideas. The control class did not have access to Knowledge Forum. Overall, discourse in the database resulted in improved literacy, a positive correlation between database activity and final grades, and to a more harmonious classroom culture.

Keywords: literacy, dialogue, knowledge building

INTRODUCTION

In North America, 25 percent of students are reading at "below basic" levels meaning that they are unable to understand or comprehend advanced material (OECD-OCDE, 2000). Fewer than 5% of the adolescents in the American NAEP 1998 assessment could extend or elaborate the meanings of the materials they read. The NAEP writing assessments also indicated that few adolescents could write effective pieces with sufficient details to support main points (Donahue, Voelkl, Campbell, & Mazzeo, 1999; Moore, Bean, Birdyshaw, Rycik, 1999). This is an appalling finding given that students have been reading and writing in school for many years before these assessments. The increasing complexity of knowledge in every domain increasingly demands sophisticated abilities for composing and comprehending written text (NICHD, 2000). Clearly, adolescents' literacy skills are not keeping pace with the societal demands of living in a rapidly changing knowledge age (Senge, 2000). Research indicates several reasons for low literacy all centering on the nature of classroom discourse. Discourse is central to knowledge creation because it is the means through which knowledge is formed, criticized, and amended (Scardamalia, Bereiter & Lamon, 1994).

Although several studies have indicated that meaningful discourse is the most relevant classroom variable for increasing literacy, this practice is not pervasive in schools (Applebee, 1996; Greenleaf, Jimenez & Roller, 2002). Unlike conventional conversation or dialogue in professional communities, classroom discourse typically conforms to a participation structure controlled by the teacher. Teachers ask most of the questions, call on students to answer and allocate turns (Greenleaf & Freedman, 1993). The discourse between teacher and students is then limited to an IRE (inquire, respond, evaluate) structure for the purpose of transmitting information (Cazden, 1988) where the teacher already knows the answer. Additionally, adolescents' evolving expertise in coping with routine school literacy tasks with the least amount of time or effort (Scardamalia et al, 1994) suggests the need to involve students in higher level thinking about what they read and write than is possible within a transmission model of teaching, with its emphasis on skill and drill, teacher-centered instruction, and passive learning. However, this 'knowledge transmission' model has had a very strong hold in classrooms for decades (Cuban, 1993). In these environments, students have little chance of becoming heard or recognized as contributing participants. As the NAEP and other results indicate student achievement with this kind of discourse does not promote reading for comprehension or writing for communication.

Bereiter and Scardamalia (1987) distinguished two types of discourse: knowledge telling and knowledge transforming. Knowledge telling is a traditional discourse used to support teaching-learning interactions, such as the IRE structure. A knowledge transforming strategy treats discourse as problem solving, an active reworking of thoughts. Bereiter and Scardamalia (1987) were reporting on the process of writing, which is also a form of discourse and one central to assessments of reading comprehension[1]. Carbonaro and Gamoran (1999) found that the more teachers emphasized both literature and analytical writing, the higher the average achievement growth of their students; conversely, students tended to gain the least when their teachers

1 For example, The NAEP reading assessments require written responses from students.

emphasized grammar. Nystrand (1997) showed that greater levels of coherence among reading, writing, and classroom discourse promoted higher achievement.

Knowledge building communities (Scardamalia et al, 1994), and learning communities (Brown & Campione, 1996) approaches to teaching and learning provide ways to integrate reading, writing, and dialogue as often as possible across all subject domains since each of these activities reinforces the other. These participatory methods actively engage students in their own learning and provide opportunities for substantive interaction among students as well as with the teacher. In these classrooms, learners focus on cognitive goals, structural features of a problem and use a knowledge transforming strategy (e.g., Lamon, Chan, Scardamalia, Burtis, & Brett, 1992). That is, they are intentional in how they approach learning. Unlike Brown and Campione's learning communities approach, knowledge building communities make use of information and communications technology that affords communication without restrictions of time and space, and encourages dynamic, democratic, and creative dialogue.

Technology affordances

A recognition that students need to actively construct their own knowledge by their bootstraps (Scardamalia & Bereiter, 1987) led to the development of a multimedia communal database application called Knowledge Forum® (formerly Computer Supported Intentional Learning Environments/CSILE). Knowledge Forum is an online environment where participants contribute ideas, ask questions, read what others have written, challenge ideas, and build upon them to advance their community's knowledge. Like other asynchronous conference systems, participants can interact at any time and from any place. Unlike other systems, Knowledge Forum provides views or working spaces enabling people to see and adjust the structure of their discourse making thinking visible. The software also provides customizable scaffold supports; external prompts that support cognition while the learner is in the process of creating increasingly complex structures (Bruner, 1983). Scaffold supports encourage students to reflect on their cognitive processes as they are thinking, reading and writing (Chan & Van Aalst, 2004).

The software also supports student-to-student dialogue that is not directly mediated by the teacher thus averting the problem of teacher-centred dialogue prevalent in traditional classrooms. Peers provide much of the procedural facilitation in their database by making connections between their understanding and others' ideas, with what is known in other disciplines, and with world knowledge. Confrontation with a variety of ideas and arguments promotes deeper reflection and enhances coherent explanations, because of the increased visibility of different ideas and how they change (Bereiter & Scardamalia, 1993). Since students must communicate through reading and writing improved literacy is a by-product of working with ideas (Lamon, Andrews & Scardamalia, 2004).

Teacher and classroom affordances

As Owston (1997) has noted the potential of new technologies for learning is likely to be found not in the technologies themselves but in the way in which these technologies are used as tools for learning. In classrooms where database discourse is supported by knowledge building pedagogy: "the teacher's role shifts from standing outside the learning process and guiding it to participating actively in the learning process and leading by virtue of being a more expert learner" (Bereiter & Scardamalia, 1993, p. 211). In these classrooms, the teacher turns more and more responsibility for learning over to students. Students define what needs to be learned, monitor their own progress and decide what to do when progress isn't being made.

Mr. K., the teacher, had used the software in the previous year for writing projects; but students in that class used the database as an informal chat space (Klonsky, 2001). In his second year using the database, Mr. K.'s goal was to use the database to foster students' ability to move beyond chats to online collaboration and as a mechanism for formative assessment. Collins (1992) has suggested that assessment should shift from an emphasis on traditional summative evaluation (in which data is acquired at the end of an activity) to include more formative design approaches (which are informed by data acquired during the planning and development of the activity). For example, providing adolescents who are experiencing reading difficulties with clear goals and then giving feedback on the progress they are making can lead to increased self-efficacy and greater use of comprehension strategies (Schunk & Rice, 1993).

It is important to note that the software is designed to support knowledge building communities. A knowledge building community is similar to a research community where members share responsibility for creating new knowledge. Participants set out their theories and ideas approaching information from various viewpoints; they consider how well diverse theories account for information; whether one theory provides a better account than another; whether complexity and parsimony are dealt with and so through discourse progressively improve their understanding. In this way, the community produces cultural artifacts (Bereiter, 2002) of value to themselves and others; success then is a result of contributions distributed across all members rather than being concentrated in a leader. A knowledge building community is guided by a system of 12 knowledge building principles shown in Table 1 below. Teachers' adotpion and appropriation of a knowledge building philosophy shows a developmental trajectory (Lamon, 2005); and will be explored in this paper.

Knowledge building principles	Definitions
Real ideas and authentic problems	Real knowledge problems arise from efforts to understand the world; creative work with ideas supports faster and more reliable learning, whereas learning alone seldom leads to knowledge innovation
Idea diversity	Different ideas create a dynamic environment in which contrasts, competition, and complementarity of ideas is evident, creating a rich environment for ideas to evolve into new and more refined forms
Improvable ideas	All ideas are treated as improvable; participants aim to mirror the work of great thinkers in gathering and weighing evidence, and ensuring that explanations cohere with all available evidence
Knowledge building discourse	Discourse serves to identify shared problems and gaps in understanding and to advance understanding beyond the level of the most knowledgeable individual.
Epistemic agency	Participants mobilize personal strengths to set forth their ideas and to negotiate a fit between personal ideas and ideas of others, using contrasts to spark and sustain knowledge advancement rather than depending on others to chart that course for them
Democratizing knowledge	All participants are legitimate contributors to the shared goals of the community; all have a sense of ownership of knowledge advances achieved by the group
Collective knowledge, community responsibility	Participants take responsibility for the overall advancement of knowledge in the community.
Embedded transformative assessment	The community engages in its own internal assessment, which is both more fine-tuned and rigorous than external assessment, and serves to ensure that the community's work will exceed the expectations of external assessors
Constructive use of authoritative sources	Participants use authoritative sources, along with other information sources as data for their own knowledge building and idea-improving processes.
Rise – above	The conditions to which people change because of the successes of other people in the environment. Adapting means adapting to a progressive set of conditions that keep raising standards.
Pervasive knowledge building	Creative work with ideas is integral to all knowledge work.
Symmetric knowledge advances	Interleaved communities provide successively more demanding contexts for knowledge work, and set into motion inner-outer community dynamics that serve to embed ideas in a broader social context.

Table 1: Knowledge Building Principles

Effects of technology on student self-concept and attitudes about literacy

Desktop publishing, web publishing, and e-mail have made it possible for students to write for real and extended audiences. According to numerous reports, this is a great motivator and encourages students to take greater care with their writing. Technology environments heighten students' motivation to become independent readers and writers and thereby increase their sense of competency (Kamil, Intrator, & Kim, 2000). Working in a technology supported classroom increases motivation. Beach and Lundell (1998) found that the information and communications technology encourages participation from students who tend to shy away from participating in face-to-face discussions, and can facilitate the free expression of alternate views. They noted how these social contexts require adolescents to contribute in ways that call on them to infer social meanings, respond in ways that are socially appropriate, and accurately communicate their ideas to an audience. This seems particularly important for students coming from other cultures (NRP, 2000). As a Jamaican student new to Canada who participated in this study said:

> Sometimes when I'm at home with nothing to do ideas will be running through my head and I'll say I'm just going to put it on Knowledge Forum. Because sometimes when I'm at home I can get really bored so I just go on the forum. It has changed my writing because at the beginning of the year I knew for sure that I wasn't a good writer because my marks weren't good as Mr. Mr. K. explained and now I'm up there with the rest of the class getting 80's and so it's good.

The hypothesis for this study was that students who engaged in online collaborative discourse would improve their literacy skills compared to a class that did not have the opportunity for online discussions. A specific focus on classroom processes and the teacher's role are highlighted.

METHOD

Participants

Thirty-eight secondary students in two Grade 9 literature classes in an inner-city multicultural school participated. A one-year literature course with students who were generally not going to university was the domain. Students were randomly assigned to courses by school administration. Researchers arbitrarily assigned one class access to Knowledge Forum. Mr. K. taught both classes on alternate days at the same time in the morning.

Materials for Assessment

The reading comprehension assessments used for this study were adapted from Campbell and Brokop's (2000) Canadian Adult Reading Assessment because they had been validated with students across Canada using the Fry (1977) and Chall (1995) readability indices (cited in Campbell & Brokop, 2000). Additionally, passage topics had been chosen by a wide array of adult students who reflected diversity in terms of race, class and gender. Finally, the focus of the tool is comprehension not word recognition-a lower level skill. The texts are grouped into levels, with each level increasing in difficulty-based on factors such as number of questions, length and readability. For this study, two 500 - word texts at a Grade 9 readability level were selected. Texts were counterbalanced so that students did not read the same text in the fall and spring.

PROCEDURE

At the beginning and end of the year, researchers administered pre and post reading assessments to students in both classrooms. Researchers and the teacher introduced the software to students in a one-hour session. Throughout the year-long course, students went to a computer lab twice a week and most logged in from home. Towards the end of the course, researchers interviewed five randomly selected students in the experimental classroom and the teacher. Beyond that, there was little communication between researchers and Mr. K. or between researchers and students.

For the experimental class, students began with an empty database. The first task was to contribute his/her autobiography to a View[2], called "Personal Autobiography". The activity, designed to be non-threatening, allowed students to familiarize themselves with the software while getting to know a little about one another's background, interests and so on. Initially, students collaborated to teach each other aspects of html, an activity that did not involve the teacher. Two out of three classes per week were carried out in the school's computer laboratory where students and their teacher used the software alone or in pairs to compose and revise their writing and to offer feedback on other's work. Occasionally, students and sometimes the teacher gathered to discuss an idea posted in the database. An analysis showed that most students also logged in outside class time. All writing from first draft to final paper was public in the database as were the teacher 's formative assessments in the form of annotations. Mr. K. also encouraged students to annotate and build onto each other's drafts.

Mr. K.'s control class typically worked in small groups; and thus the entire class could not review all exchanges regularly. These face-to-face conversations were transitory, and unlike database communication which preserves discourse, allowing students to return to their ideas and study them from a variety of perspectives (Hewitt, 2004).

Occasionally, in both classes, there were whole class discussions on the writing topic, reading a text or discussing what the teacher called "dangerous ideas". These were ideas contributed by the teacher or students to a literal snake basket. These included ideas such as morals are relative, religion is dangerous, or different cultures can't coexist as well as quotations from writers. The curricular content for both secondary classes was the same: creative writing, research and research reports, and personal essays. As the year progressed, there was a noticeable shift in the experimental class as students began to assume some ownership for discourse in the database. As one example, early in the year, students had written creation myths and their last assignment was

[2] A View in a Knowledge forum database allows participants to organize their discourse according to problems or issues graphically. Notes, the basic way to contribute to a discussion, can be copied from one view to another.

to write a science fiction story. Noticing that the first assignment was to write a creation myth from long ago and a science fiction story to take place in the future, one student wondered about the concept of time. He created a view for discussion and the rest of the class joined. Their ideas were diverse: time is man made, time is universal, or time is a cycle. A section of their discussion is shown in Figure 1 below.

Figure 1: A Knowledge Forum View with Sections of a Note Thread.

RESULTS

As well as the Canadian Adult Reading Assessment, final grades for experimental and control groups were examined. For the experimental group, Knowledge Forum's Analytic Toolkit was used to assess quantitative activities (i.e., expressing ideas in writing, building onto other's ideas, reading) as was the teacher's database activity. Towards the end of the academic year, video interviews were conducted with the teacher and five students in the experimental class.

Classroom Culture

Mr. K. reported that students in the experimental class had higher attendance and assignment completion rates than students in the control group. For example, the first assignment saw a completion rate of 100% for the experimental class versus a 30% completion rate for the control class; and according to the teacher this pattern continued. This result convinced Mr. K. that the database had a profound effect (Klonsky, 2003). He stated that he had never seen a group of students so supportive of each other:

> I wish you could see this from day to day because it is really impressive and so important. To me it is a revolutionary change. I just do not see the same thing going on in the other class. Now, once again, one might attribute it to the unique dynamic of that group but I don't think so. All of them are Grade nine students and these kids happened to have come into a situation where they really feel comfortable and they've been very successful and it's working.

In the interviews with five randomly selected students, four enjoyed interactions in the database and believed that their thinking, writing and reading had advanced through feedback from others. One student, learning English as a second language and without Internet access from home, was not comfortable discussing her ideas in the database. As one of the other four students summarized:

> I would say it is a pretty interactive program that allows a person to develop their skills based on what other people might suggest and it is a pretty open system because you don't necessarily have to follow or to please anyone who annotates your work or builds onto your work. You can choose exactly what you want to do and it builds on your independent level of study and thinking as well. Your analytic skills develop by using this program itself.

Both the teacher and four of the five interviewed students believed that working in the database developed communication skills and literacy skills as well as more collaborative classroom culture. They also agreed that formative assessments by the teacher and other students provided more opportunities to improve their writing. A sample of students' discusions shown below in Table 2 illustrates their online discourse:

My Ideas on TIME
by Lennie L.
Last modified: 2003, April 09 (09:26:36) by Lennie L.

My theory:[3] Time is only what we make of it. It is something in which we use as a guideline so the whole world can run smoothly. Now if no one if calculating time, does it still exist? My answer to this is no.

New information : This is because if you have two clocks both set exactly to the same time and then you bring one into space and come back say a week later the time on the clock that went into space will be different than the clock that was on earth.Because time never existed we only created it, it is not universal. Without time the world maybe would not have advanced. Without recording days and hours that have gone by everything and everyone would be out of sync. If time were to actually exist when would it exist? In the past, present, or future even? In everyone's mind it appears that the past had existed but the only thing that really exists that you can control is the present and the future. Now some people say that you do not have control over your future but I believe you do. So if time does not really exist can we bend it? The answer to this in my head is yes. You can only bend the near future. In your head you can make time go as fast or as slow as you desire. Now time is only calculated as a mathematical equation so we can change this. Could we use the laws of mathematics to reverse time or speed it up? Anything is possible.

I sometimes feel the hands of time closing in on me. When I am trapped within its limits. It almost feels like an impenetrable barrier that is set on two speeds, slow and fast. You want to pass the barrier because you want to desperately know what is beyond it but you know you can't. It is when we break this barrier, this barrier that is time, that we will be able to go anywhere beyond this universe. So what is this barrier? Well if I knew I am positive that I would't be spending my time (get the irony!) at VRA. Though, I do know that time is physics and we have bound ourselves to these laws of physics because we are ignorant people and we want to live lives that have meaning and in the end will wrap up into a perfect package as time passes by our gravestones.

Build-On Notes

To Lenny, Somehow sensible comments
by john c.
Last modified: 2003, April 07 (16:14:58) by john c.

So then if the gravity is higher , on a watch, the gravity will push the hands down? What does that have to do with gravity then? If you have a clock that works on the sun, then where does gravity come into play? People measure time using clocks and sundials, but taking your clock out into space isnt the reason you will age quicker or slower outside of earth. Time acts upon us whether or not we have clocks. Clocks don't mean we created time.

Somehow Sensible Comments
by Lennie L.
Last modified: 2003, April 07 (22:24:47) by Lennie L.

John, in response to your comments it has been proven that clocks tick at different speeds on Earth and in Space. You see there is something called gravity which puts pressure on different objects forcing them to do certain things. In space there is less pressure than on Earth because there is no gravity. Now with less pressure on a clock in space it would either move faster or slower. Regardless which one the point is it will move FASTER OR SLOWER than the one on Earth.

[3] This is a scaffold support in the software.

You see this is how I came back to the idea we invented time. Because it is a worldly measurement and does not prove to be the same outside the earth how can it really fully exist.

John you say "It is true that people age quicker on earth than in space, but that has nothing to do with clocks and peoples' measure of time." I ask you then what is aging if it has nothing to do with our measurements of time? Who is to say that our lives start when we are born? Maybe they start when we end. Time is a way to bring stability to havoc. We need time to understand ourselves and what is happening around us.

TIME
by naguib s.
Last modified: 2003, April 09 (09:30:37) by naguib s.

I need to understand To me I find it quite incomphrensible to believe that time actually repeats itself. For example, if looking at a solar calendar, the 365 days repats itself but how do we know exactly that it is repeating itself if time is only exsistant for a fraction of a second. To an even further extent I wonder if time really exsists? We can not consider the futur time. The past is time that has already passed. The present is only there for only a mere instance. the matter is quite large and is quite hard to answer with only my understanding. To prove the complexity of this subject, the moment you finish reading this it will already be the past and that moment in time has passed and will never exsist again.

Table 1: Students' online discourse

Quantitative Results: The Canadian Adult Reading Assessment (CARA)

Students in both classes were asked to read an expository text ("The Halifax Explosion" concerning events that occurred during WWI. "Why Birds Fly" that focused on anatomical and physiological characteristics of birds affording flight.). Texts were counterbalanced so that student who read about Halifax in the fall read about birds in the spring. After students had read the text, it was removed and students were asked to (1) retell the story and (2) to answer 10 questions that required a factual or an inferential response (e.g., "Who was to blame for the Halifax explosion?" Answers were not explicitly provided in the text.

CARA MEASURES				
Questions				
Group	Pretest Mean	SD	Post-test Mean	SD
Experimental (N=16)	9.63	3.89	22.25	8.01
Control (N=14)	8.57	3.97	15.46	5.93
Recall				
Group	Pretest Mean	SD	Post-test Mean	SD
Experimental (N=16)	8.94	2.35	11.31	2.50
Control (N=14)	9.07	3.11	10.36	3.34

Table 3: Mean Pretest and Post-test Question and Recall Scores for Experimental and Control Classes.

A multivariate analysis was conducted[4]. Pretest scores for the question section of the assessment did not vary between groups. They were used as a covariate for the post-test scores. Post test scores revealed that the experimental class performed significantly better than the control class F (1,26) = 34.44, p < .0001 for answering questions. There was also an interaction between group and questions F (1,26) = 5.66 p < .04. Pretest scores for the recall section of the assessment for the experimental and control groups did not differ and were used as a covariate for the post-test recall scores which did differ F (1,26) = 77.84, p < .001. There was no interaction between group and recall F (1,26) = 2.76, p > .1. There was an interaction between questions and recall scores F (1, 26) = 27.72, p < .001. There was no group by question by recall interaction. Clearly, the experimental group outperformed the control group on both measures. It is also not surprising that there was a question by recall interaction since both were related to the text. The one noticeable difference was that there was no group by recall interaction. There are two possible explanations: the first is that there was a ceiling effect for the recall test; and the second was that recall may be a measure of knowledge telling where the task for students was to use a copy delete strategy that might not be expected to differ between groups.

[4] Thanks to an anonymous reviewer who suggested this analysis. This led the author to include only those students who had competed the pretest, post-test and for whom there was a final grade.

Final Grades

Final grades (not including database activities) for the two classes were examined. They revealed a significant difference between classes $F(1,26) = 6.13$, $p < .03$. Additionally, four students in the control class did not achieve a grade of 50% and one student in the experimental class did not.

Group	Mean Grade	SD	Median
Experimental (N=16)	66.31	12.67	64
Control (N=14)	53.07	16.59	52

Table 4: Mean final grades for experimental and control classes.

Knowledge Forum's Analytic Toolkit

The analytic toolkit underlying Knowledge Forum affords a detailed examination of database activity (See http://analysis.ikit.org/atk/atkdoc.html for details) and was used for the same exprimental participants.

Measure	Mean	SD	Median
# Notes created	16.18	8.54	11
Percent of notes read	40%	23%	35.8%
# Revisions	57.41	52.48	33

Table 5: Analytic Toolkit Resuts for the Students

Previous research (Lamon & Power, 1997) showed that reading in the database was correlated with advance placement course results but writing was not. In the present study, both writing, reading and number of revisions were significantly correlated with final grades as can be seen in Table 4. It is now possible to examine the number of build-on notes and number of annotations: both of which are sensitive to collaboration in the database. However, in the database these students used, neither measure was available in the ATK; nor could they be calculated in a conversion of the database to a later version. This was a limitation in understanding effects of student collaboration on literacy development.

	# Notes Created	% Notes Read	# Views worked in	# Revisions	Final Grades
# Notes created		0.89††	0.58†	0.80††	0.66††
Proportion Notes Read			0.44	0.56†	0.61††
# Revisions					0.47

Table 6: Correlation Matrix for ATK measures and Course Grades (†† $p < 0.01$, † $p < 0.05$).

Teacher Analytic Toolkit Results

As well as examining student results in terms of database activity, it was of interest to examine the teacher's behaviour in the database. This revealed a pattern characteristic of teachers with some experience in using Knowledge Forum but who are not experts in developing and sustaining knowledge building communities in their classrooms (Lamon, 2005). As the results demonstrate, Mr. K made 172 annotations and 45 build-on notes. He did not provide students with opportunities to create their own views since the teacher created 12 of the 13 views.

# Notes Created	% Notes Linked	% Notes Read	# Notes in Build-Ons	# Views Created	# Annotations
61	75.4%	76.4%	45	12	172

Table 7. Analytic Toolkit Results for the Teacher

DISCUSSION

Results indicated that computer supported collaborative learning affected literacy development in terms of a task that required a knowledge transforming strategy (answering factual and inferential questions) and in terms of tasks requiring a knowledge telling strategy (recall of texts). Experimental students outperformed control students - an indication that students even when working individually are able to work critically with ideas. Additionally, final grades correlated with database activity suggesting that students' individual work (number of notes written, revisions) and collaborative work (proportion of notes read) is related to course outcomes. That the Analytic Toolkit measures that could not determine effects of collaboration (number of annotations; number of build-on notes) was a serious limitation. Unlike many educational interventions this effect isn't compromised by teacher intervention, a criticism frequently directed at educational reforms that are, in part, dependent on teacher differences. Participating teachers in reform efforts are early adopters of information and communications technology; but teachers in control classes may not be (see Doubler, Laferriere, Lamon, & Rose, 1993) for a discussion on early adopters and ICT).

When students were given the freedom to express ideas, in their discussion of time, the nature of online discourse changed from a task focus to idea centered. What the electronic database did allow was the emergence of students' discourse as the primary medium for understanding what they were reading and writing. Mr. K. read many notes in the database and his responses provided students with constructive feedback for improving their writing. He also asked for a reconsideration of ideas, and alluded to other literary sources. Finally, the database afforded opportunities for three of NRP's (2000) recommendations for reading comprehension: comprehension monitoring, cooperative learning, and answering questions with feedback.

Students of all ages construct scripts for school. Based on years of similar experiences, they develop scripts that include listening to lectures, predicting what will be on texts, using copy delete strategies for summarizing texts and memorizing facts. Although, Mr. K. released agency to students in terms of assessment literacy, he did not overtly encourage students to view the knowledge of the collective as the focus. If the goal is to advance the knowledge of the group, students must first understand how their knowledge is limited and then seek to improve it. New contributions by one person will influence subsequent investigations by others and so individual understanding is driven forward by the dual need to be familiar with the knowledge of the collective, and the desire to advance that knowledge. Implicitly, Mr. K. may have realized this in his comment:

> The idea that many heads are better than one that you may be the expert or may have learned more or have a better education but on a specific matter of work that does not mean that there isn't a sufficient amount of knowledge and thought in that classroom that you can't advance further than the teacher. My philosophy is that there is more out there in the classroom by way of resources than the teacher knows.

Nonetheless, the fact that all students were assigned the same set of tasks argued against a knowledge building philosophy. Even though students' took some control of the curriculum the teacher assigned most of the content: that is, all students were required to do the same thing at the same time. Reconciling the inevitable tension between mandated curricula and knowledge building community development – that is, the trade off between depth and breadth was a challenge in this classroom.

The teacher's many online contributions suggested that he may have been more involved in the discourse than is common in classrooms led by expert knowledge building teachers (Lamon, 2005). Expert knowledge building teachers organize their classrooms so that problems of understanding and knowledge advances in the database are made public beyond the database. Beginning knowledge building teachers intervene very little in the database but when they do they are more directive in terms of the curriculum. At the intermediate stage on a developmental trajectory in appropriating a knowledge building philosophy, teachers intervene frequently in the database not so much to direct students but to offer constructive feedback. A goal for further research is to examine the role of teachers' online discourse in blended learning environments; and how teachers' professional development might foster teachers' adoption and appropriation of computer supported collaborative learning.

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Language Learning in a Virtual Classroom: Synchronous Methods, Cultural Exchanges

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Abstract. Exploring language development through using synchronous (real-time) voice and chat technology will be the focus of this paper. Researchers interviewed students, teaching assistants, and teachers of an online English as Second Language program based in Taiwan, using grounded theory to begin generating a theory of language learning using this new technology. Students of all ages reported preferring the online environment because they were less fearful of speaking online due to the anonymity afforded by the technology. Engaging article content motivated learners to interact with teachers and, as they became comfortable to interact collaboratively with each other. The opportunity to speak English with native speakers enabled students to obtain the necessary fluency for business, school and travel.

Keywords. Synchronous communication, voice over Internet protocol (VoIP) technology, computer supported collaborative learning (CSCL), English as a Second Language (ESL)

INTRODUCTION

Lee[*], a 24-year-old native of Taiwan who speaks Taiwanese, Mandarin and English, began studying English in elementary school and continued through university. Initially, Lee was not interested in learning English as the lessons were uninteresting and there was no one with whom to speak English. However, she wanted to please her parents by studying English. Years later Lee made plans to travel to the United States, and she sought an online course to prepare her to communicate with the Americans she would encounter. She joined a course offered through the Internet using synchronous (real time) voice and text chat, taught by native English speakers located in the United States. Teaching assistants located in Taiwan, who were bilingual in Mandarin and English, co-taught the course, called "Speak2Me LiveUSA," offered by Ladder Publishing, Ltd. Students from Mainland China and Taiwan logged into the course to discuss articles primarily about American culture. Through this interaction, Lee improved upon her English, learned to use American idioms, and became familiar with English as a tool to understand American thought. A year later, Lee visited the United States, taking a job at a large amusement park so that she could travel and experience a culture outside her own.

Stories similar to Lee's will become more prevalent during the next ten years as access to online learning expands and opportunities for cross-cultural exchanges are made possible through synchronous technologies. Through online learning, access to learning other languages will become more convenient and flexible. But more importantly for second language learners, the technology of online learning offers the possibility to interact with members of the target culture, thereby contextualizing language learning. Wong Fillmore's (1991) model of language learning in social context recognizes the importance of interaction with target language speakers for the development of a second language. When language is contextualized, speech is used productively, shared background knowledge is utilized, and the target language's thought pattern is acquired. Given the opportunities presented for contextualization and learning with someone from the target language, language development in a synchronous online environment with voice over Internet protocol (VoIP) technology can be just as effective as face-to-face language learning in a brick and mortar classroom. Indeed, with rigorous course design, synchronous online language courses may enhance and even surpass face-to-face courses, as it well must given increasing global ties among nations.

Language learning through the Internet will increase with mounting pressure to learn other languages as we enter a new expansive area. Every expansive area in the history of humankind has coincided with the operation of factors which have tended to eliminate distance between peoples previously hemmed off from one another (Anderson, 2003). Language development meshes with the Computer Supported Collaborative Learning

[*] All names are pseudonyms and identifying information has been changed.

(CSCL) ten-year agenda as it focuses on the intersection of technology with the socio-cultural aspect of learning another language through collaborative methods that bring together very different cultures around topics of common interest. As CSCL's aim is to explore how technology can be used to facilitate collaboration, we foresee language development using synchronous technology as a part of the new innovations in education arising out of the increasing availability of high-speed Internet access and use of VoIP.

PURPOSE

The purpose of this exploratory study is to discover the interactions necessary for individual language development in an online, synchronous, voice-enabled environment, using a sociocultural approach resulting in a preliminary grounded theory. At this stage of the research, interactions will be defined generally as communication that takes place in English among the learners, teaching assistants, and teachers.

This preliminary study endeavors to begin the development of a theory about learning another language in a synchronous virtual environment using VoIP. This paper seeks to make its contribution to the inductive process of language development theory building by adding phenomena discovered when researching an English as a Second Language program offered by Ladder Digital Education Corp., and enabled through the synchronous (real time) technology of VoIP, in contrast to evaluating the use of the program's features. The synchronous technology of voice over IP enables communication, educational avenues, and community building across cultures, previously considered difficult due to the constraints of the text-based, asynchronous (not occurring at the same time) nature of online learning.

McIsaac and Gunawardena (1996) affirm that the concept of interaction is fundamental to the success of learning. Language use, the way we use or do not use words (e.g., silence) expresses a way of thinking and interacting (Ochs, 1986). Given this orientation, individuals who have a strong desire to be accepted as members of a new linguistic community must interact with that community.

The research questions this study seeks to answer include: How does an online, synchronous, voice-enabled environment facilitate language learning? How should each class be designed to encourage collaborative learning? What kinds of interactions occur?

METHODOLOGY

To explore how interaction enabled through online, voice-enabled synchronous communication facilitates language learning, the grounded theory approach developed by Glaser and Strauss (1967) was used in this study to generate a theory from data collected because, as yet, no theory exists for language development in a synchronous, voice-enabled online environment. This is a preliminary study based on initial findings of a theoretical sample of 18 informants ranging in age from 20 to 35. Data collected were coded using AtlasTi,, and constant comparison was used to examine the data and place it into categories according to their relationships with each other to allow themes to emerge. As participant observers, we took care to view the data with respect for the Chinese culture and the beliefs of Confucianism that underlie education in China and Taiwan.

Data Collection

The primary data for this study includes data collected between October 2003 and November 2004 through interviews of six Speak2Me (S2M) Live USA students, ten teaching assistants, and two S2M staff members. Interviews were conducted in order to capture the data through the words and voices of the participants. Interviews were semi-structured and conducted face-to-face in Taiwan, through Yahoo Instant Messenger Voice Chat, and through e-mail. The data collected was triangulated using teacher field notes, teaching assistant notes, Speak2Me administrative policies related to teaching and providing learner support, and information related to standardized tests that certify English proficiency.

Analysis and Results

The data collected was analyzed using grounded theory, which uses a constant comparative method of data analysis. During the process of open coding the data, we found that through synchronous technology, the role of the English language learner changes from isolation to connectedness, from unaware to informed, from passive to active. The impact of the connected, informed, and active learner is manifest in many ways. Our informants reported having access to an unprecedented number of ways to learn English—after-school cram school, EnglishTown on the Web, private tutors, English foreign language magazines sold on newsstands, CDs, and television and radio programs. While many opportunities to read and write English exist, there are fewer opportunities to hear English spoken by Americans or other English-speaking people. Informants commented that often nonnative English speakers teach English classes and they mispronounce words.

Several informants stated that often the content of the English lessons is boring. Frequently content is another repetition of lessons previously studied throughout grade school, middle school, and high school. Jason remarked that content on Chinese dynasties is covered in their history classes and repeated in their English classes. Using English to study Chinese dynasties in a Chinese classroom provides an opportunity to use English vocabulary. Yet such a study is outside the context of a conversation with English speakers. Jason relayed that with S2M Live USA, learners enjoy articles about current topics such as sports, new technology, celebrities, movies, health fads, and other topics relevant to American culture. When the articles stimulate learners, discussions ensue around topics to which the students feel connected.

Informants said they enjoy learning about the ordinary events of life as shared in the virtual classroom. Even though learners can read about these life events, they enjoy talking about them with Americans. Through the discussion of the articles, teachers and learners exchange stories of enjoying similar things in life—celebrating holidays, weddings and births, their favorite coffees and teas, and favorite local specialties. For example, in a lesson that discussed American baby showers, students shared Chinese and Taiwanese traditions. Interacting synchronously gives learners access to a culture's stored knowledge.

While the unique differences in Chinese and American traditions, food, celebrations, rituals, and other topics discussed provided interesting topics to discuss, the discussions took place within a context that both American instructors and Chinese learners and teaching assistants could identify with and relate to—the classroom. The classroom setting, even though virtual, provided a representation for how to participate and exchange information in a familiar setting. Jason expressed the need for having an image or representation of the topic of a lesson. Jason mentioned that when neither he nor his relatives had experience with the topic of a lesson, he could not find the words to participate in the discussion. Initially, both American instructors and Chinese learners were uncomfortable in the classroom as the American instructors expected the Chinese learners to speak at will as students do in American brick and mortar classrooms. Moreover, American teachers were initially uncomfortable with the long, reflective pauses in the synchronous voice communication. However, as time has passed, instructors and students have become more comfortable interacting spontaneously and collaboratively, at times with the students greeting each other at the start of the class and prompting one another when they have difficulties.

Despite prevalent access to technology and a desire to improve one's self, many individuals have a basic fear of speaking English with native speakers. Jason observed, "We Taiwanese—if we can't speak English very nice, very fluent—we want to learn English and speak, but we are afraid. We are afraid to talk with foreigners because we are afraid if I can't speak the proper words or listen to it." Results suggest that communicating using a synchronous Internet connection lessens some of that fear. Because students, teachers, and teaching assistants do not see each other face to face in the virtual classroom, novice speakers said they felt more comfortable speaking. Lee mentioned feeling "nervous to join the class," yet participated in a number of lessons. Lee said that the ability to use the chat box instead of being forced to speak aloud was a helpful feature in lessening her anxiety.

Conversely, some students will use the technology as a reason for not speaking or participating beyond typing comments into a textbox. Teaching assistants and students interviewed spoke of some students typing in the textbox that they "do not have a microphone that works", when in fact they were not experiencing such problem.

Informants stated that Chinese and Taiwanese children begin studying English in elementary school. Many reported attending cram schools after school, often until university. Moreover, they said that they were never really interested in learning English until they reached university level and began planning for a career. Proficiency in English is seen as a means to good jobs, opportunity, and access to information on the Internet. They want to be understood, use slang and idioms correctly, and speak English, not *Chinglish*. Some informants planned to attend school in the United States; others looked forward to travel in the United States, and still others planned to work in a country where the dominant language is English. During the summer of 2004, Richard took a job as a camp counselor in a northern state in the United States. He was hired for the position in part because of his English language fluency. Upon his return to Taiwan, he was in the Speak2Me LiveUSA classroom the very next day, reporting on his adventures, not the least of which included calling his mother the day after arrival and asking her to send his warm jacket. "I'm from the tropics, and this was like winter even though it was summer!" he exclaimed. Two observations can be drawn from this story. One, that Richard felt enough of a kinship to his teacher, teaching assistant and fellow students to join a class immediately upon returning home, and two, that his English had improved.

The Taiwanese teaching assistants also responded in the interviews that they wished to remain proficient in English. They had traveled to the United States, Australia, Canada and England, and obtained jobs based on their ability to speak English well. When they returned home they found that they, too, had limited opportunities to speak English with native speakers, and feared losing their ability to speak fluently. John said that becoming a teaching assistant for Speak2Me was not only a good opportunity as it allowed him to "keep using English at a more meaningful level, rather than just say ‘Can I have a chicken sandwich?’ Without the opportunity to speak English online, John said he would “not use it, period.”

DEVELOPING A GENERAL THEORY ABOUT LANGUAGE DEVELOPMENT AND SYNCHRONOUS TECHNOLOGIES

Developing a general theory about language development through the synchronous communication of VoIP through the Internet requires joining the fields of ethnography, CSCL, computer-assisted language learning, distance education, and language development. Each of these fields offers its respective theories pertaining to the interaction of teachers and students through the Internet while learning English. In its Joint Policy Statement, CALICO declared in 1999 that “the field of CALL is inherently multidisciplinary” (CALICO, EUROCALL, & IALLT, 1999).

One field in which researchers have been describing, speculating, accumulating facts, and creating guiding theories for more than 40 years is language development (Bohannon and Bonvillian, 2001). Ochs (1986) suggested that the development of language is modeled by communication with others as sociocultural information is generally encoded in the organization of conversational discourse. Language learners acquire sociocultural information as well as situationally appropriate ways of turntaking, speaker selection, interruptions, and conversational sequencing, along with grammar, vocabulary and pronunciation. Vygotsky (1986) wrote that language is a tool to develop thinking. Studying lists of vocabulary is not language learning in and of itself. Language provides the entrance to a culture as it informs the learner how thought is structured in that culture.

Computer Assisted Language Learning (CALL) Facilitated by Synchronous (Chat/VoIP) Technologies

To facilitate learning when learners, teaching assistants, and teachers are separated geographically, communication among the participation is mediated by technology. For over 20 years, computer-assisted language teaching has been used to teach foreign languages, with the past decade in language learning theory seeing a shift from highly guided to a learner-centered, constructivist learning environment (Ruschoff, 2002). The new technologies,such as those afforded by synchronous VoIP, offer great potential for innovation in CALL. Indeed, selected communicative behaviors can reduce perceived distance between people. Through asking questions, addressing each other by name, initiating discussion, and sharing personal examples, a sense of psychological closeness (Woods & Baker, 2004) is perceived. Gunawardena and Zittle (1997) describe humanizing communications between individuals in computer-mediated environments as a predictor of overall learner satisfaction.

Development of a Virtual Community

Supporting one another in a non-judgmental way leads to community, sharing, trust building, and a sense of belonging that enables individual learners to be risk takers. Wenger (1998) wrote

> “[t]he concept of practice connotes doing, but not just doing in and of itself. It is doing in a historical and social context that gives structure and meaning to what we do. In this sense, practice is always social practice. It includes the language…[and] the implicit relations… (p. 47)”

When children begin learning a second language with friends, they are usually at a beginning level (e.g., “throw me the ball”). Yet adult language learners usually do not get the chance to interact at this level. Instead, adults are often in situations where greater language fluency is demanded of them, such as explaining where they need to go, or talking with teachers about their children. In the online synchronous classroom, adults and children are able to interact in a safe environment, with no pressure to speak. Gray & Tatar (2003) examined Tapped In to understand how symbolic systems mediate interpersonal interactions and refer to shared cultural models. In their case study they found that their participant’s use of chat allowed interpersonal interactions inside group boundaries. Likewise, students, teaching assistants and teachers in LiveUSA routinely use the text box to exchange greetings, clarify vocabulary, and otherwise communicate informally. This informal text-based communication is enhanced by the use of VoIP, which provides the opportunity to listen and respond verbally to others, adding nuance and depth to meaning making and relationship building.

Limitations

Limitations of this study must be identified. As participant observers who have participated as online instructors since Spring 2003, we acknowledge our prior, tacit knowledge and its impact on our theory development.

Other limitations are the self-selection process that most certainly occurred as the result of the synchronous nature of this language learning program. Individuals who are not technologically savvy and/or lack the time to learn new technologies may have found working in the online LiveUSA environment too difficult to master. Therefore, our sample is limited to those who possessed the requisite computer skills, access to high speed broadband connections, and patience necessary to tackle new technology.

Future

As the virtual community has formed, roles have changed. The pattern of interaction is becoming group based, and the question is “What is the right combination of task, people, and technology?”

CONCLUSION

Our initial results suggest that synchronous VoIP technology facilitates language learning across cultures through stimulating virtual classroom interaction through the use of engaging content and collaborative teaching methods. Online language learning offers many benefits—contextualized interaction with the target culture in a safe learning environment. The ability to use synchronous (real-time) voice and chat technology engages learners in the language development process, regardless of ability or level of anxiety. Students are able to learn idiomatic American English in a location of their choosing, making learning English as well as maintaining fluency accessible for many learners who otherwise could not attend classes.

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Assessing Learning Outcomes in CSCL Settings

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Abstract. A variety of models and methodologies for assessing learning outcomes in CSCL settings have been reported in the literature, most of which were developed either within the framework of assessing levels of critical thinking or phases in problem solving. These generally assess outcomes at the individual level though the learning context was clearly a social collaborative one. Recent studies on the characteristics of productive online collaborative discourse have identified features at the group/community level that cannot be sufficiently described at the individual level. Building on the theory of knowledge building (Scardamalia & Bereiter, 2003) as a social intentional activity, this paper proposes a model of assessing learning in CSCL contexts as group/community outcomes with four inter-related but distinct dimensions: a social dynamic for sharing and open exploration, a progressive inquiry orientation, a socio-metacognitive orientation and a communal habit of mind. An application of the model is reported and the implication of the findings is discussed.

Keywords: assessment, online discourse, knowledge building, self-directed learning, critical thinking

INTRODUCTION

The use of CSCL in the formal curriculum has been gaining in popularity and importance. The increasing use of online discussions as a means of supporting collaborative learning has also raised the concern and interest of both researchers and practitioners on the issue of how to assess learning outcomes in such contexts. The assessment of learning outcomes have traditionally focused on the learner's mastery of knowledge, skills and understanding in specific subject areas. However, CSCL has often been adopted by educators who value the capacity of the learner to undertake autonomous learning and to problem solve as important outcomes to target. It is thus often the case that conventional methods of assessing learning outcomes are considered as inadequate for use in CSCL contexts. Further, it is often the assumption that social interactions and/or collaboration play an important role in the learning process and influence the quality of the outcome.

It is not surprising to note that much of the literature on assessing learning in CSCL contexts have originated from research in the adult learning area, which has been very much concerned with the concepts of critical thinking and self-directed learning. Another orientation in the assessment of learning outcomes was that of evaluating the quality of argumentation. Different rubrics have been developed on the basis of these conceptualizations of learning to analyze protocols/online discourse collected in computer conferencing systems. Reports on such research have consistently argued for the critical importance of social interaction to the learning process from a theoretical perspective. However, the actual rubrics were designed to assess the quality of the messages posted by individuals. Such assessment can only reveal the quality of individual learning. The contribution of the computer-mediated communication process to the learning outcomes, or indeed the nature of the collaboration and its relationship to learning is not clear.

Analyses of participation and social interaction form another strand of research in CSCL, contributing to our understanding of the social milieu of the learning contexts concerned. However, the educational link between the social interactions and the learning outcomes are not clear. For example, what kind of social dynamic would facilitate learning? Does discussion necessarily lead to enhanced learning? (Gunawardena, Lowe, & Anderson, 1997) reported on an analysis of a discussion forum transcript and concluded that "… the forum, which was perceived as a very valuable learning experience by the participants, …… was not unlike the type of informal interaction that takes place at breaks or during social activities at face-to-face conferences or professional activities." (p. 427). It is tempting, and yet not valid, to assume that when a group of learners communicates on an electronic platform about the object of their learning, collaborative learning takes place. In other words, there is a need for research to establish a better understanding of the criteria/conditions for learning contexts supported by computer-mediated communication platforms to qualify as CSCL contexts.

This paper argues for the need for assessment tools that can assess learning as group/community level outcomes and that such tools will in turn contribute to a better understanding of CSCL. It then proposes a framework for such an assessment tool based on earlier work by Law & Wong (2003) that built on Scardamalia & Bereiter's (2003) theory that collaborative knowledge building is a social intentional activity with distinctive characteristics.

ASSESSING SELF-DIRECTED LEARNING AS OUTCOME

As mentioned earlier, many of the assessment rubrics developed for analyzing self-directed learning outcomes have been developed on the basis of literature in the area of critical thinking. For example, Henri's (1992) model for analyzing cognitive learning outcomes was a modification based on Ennis's (1986) taxonomy of 12 cognitive skills related to critical reasoning and consisted of five categories within the cognitive dimension: elementary clarification, in-depth clarification, inference, judgment and strategies. This model was designed for use in analyzing computer conferencing protocol. However, this could equally be used to assess critical reasoning as encapsulated in individual pieces of work. Indeed, it was designed to assess the quality of individual messages in the conference and thus provide information about the learning outcome of individual learners. It does not highlight the social milieu and its significance in relation to the learning outcome. Mason (1992) proposed that the content analysis should illuminate on how the discourse content builds on the contributions from other learners as well as from external sources. For example, has the message content under review built on previous messages? Has it drawn on the author's own experience? Has it referred to relevant materials within or outside the course?

Garrison (1991) developed an interaction analysis model for analyzing online discourse that similarly focused on assessing critical thinking, but at the same time highlighted the social process of negotiation and knowledge co-construction. This model comprised five phases: sharing/comparing, dissonance, negotiation, co-construction, testing and application, which paralleled and built on a conceptualization of critical thinking as a five-stage sequential process: problem identification, problem definition, problem exploration, problem applicability and problem integration. Indicators were developed to assess the stage of critical thinking the learner was in. However, though one can rationally describe the general trajectory of development in problem solving (or inquiry), the processes involved are often cyclic rather than linear. This may be one of the reasons why there were reports on the difficulties in coding the stage of critical thinking (Newman et al., 1997).

As an alternative to developing indicators for each of the stages in critical thinking, Newman et al. (1997), following Henri's (1992) model of identifying surface/deep processing dichotomies, developed 20+ pairs of opposites as indicators for all of the various stages of critical thinking. For example, one pair of indicators for the problem exploration phase was "*welcome new ideas*" and "*squashing, putting down ideas*". These indicators were grouped under 10 headings: relevance, importance, novelty, outside knowledge/experience, treatment of ambiguities, linking ideas, justification, critical assessment, practical utility and width of understanding.

UNDERSTANDING CSCL AT THE LEVEL OF TEAMS

It is evident from the above review that the various assessment methods were underpinned by theories of learning which assume the role of social interactions to be important to the learning process. On the other hand, the exact role played by social interactions in supporting learning has not been addressed adequately in these theories. Gunawardena et al. (1997) highlighted the need to recognize that there are two kinds of knowledge creation taking place, one taking place at the individual level and the other at the group level. They used a patchwork quilt metaphor comprising five phases of negotiation and co-construction (sharing/comparing, dissonance, negotiation/co-construction, testing tentative constructions and application of newly-constructed knowledge) to describe their understanding of the interdependence and interaction between the individual and the social construction of knowledge. According to this conceptualization, each phase represents a higher level of mental functioning and the online discourse can be coded using this model to indicate the level of knowledge co-construction in the message. The co-construction of knowledge is the pattern produced by the *totality of the discourse*. Analyses of online discourse using this model gave support for the argument that collaborative advancement of knowledge is not a "natural" outcome of people working or interacting together. Social knowledge construction perceived as a very valuable learning experience by the participants may be predominantly within the phase of sharing information (e.g. de Laat, 2002). Further, a debate format of online discussion hindered the desire of participants to reach a compromise or synthesis and thus the group's ability to move beyond phase III (Gunawardena et al., ibid.).

The five key characteristics summarized in the Collaborative Learning Model developed by Soller et al. (1998, quoted in Soller 2001) to characterize effective collaborative learning interaction also focused on the characteristics of teams rather than individuals: participation, social grounding, active learning conversation skills, performance analysis and group processing, and promotive interaction.

ASSESSING KNOWLEDGE BUILDING OUTCOMES: A FOUR DIMENSIONAL MODEL

Scardamalia & Bereiter (1991) put forward a notion of collaborative knowledge building as a useful paradigm for conceptualizing learning as social practice which resembles the way of life for those on the leading edge of scientific research. Central to this theory is the concept of collective cognitive responsibility for the advancement of knowledge (Scardamalia, 2002). This concept goes beyond the simple sharing of responsibility across members in terms of overt tasks, and places a particular emphasis on the cognitive dimension of the collaboration: "*they will also take responsibility for knowing what needs to be known and for insuring that others know what needs to be known*" (p. 68). Scardamalia (ibid.) observed that cognitive responsibility is harder to maintain than responsibility for tangible outcomes and put together a list of 12 distinctive characteristics that sets off a knowledge building community from other kinds of communities. These 12 characteristic socio-cognitive dynamics are generally referred to as the 12 *Knowledge Building Principles*. Knowledge building is a social intentional activity of a community which by definition cannot be achieved by individuals in isolation. Knowledge building discourse is thus by nature different from ordinary social discourse and demands distinctive characteristics of the technology for its support.

Law & Wong (2003) reported on a set of scoring rubrics to assess the learning outcomes for 43 groups of students from 8 classes that participated in a "Peer Tutoring Project", which was an online collaborative learning project lasting for about 10 weeks and involving 250 students from five secondary schools in Hong Kong. The online platform used was Knowledge Forum®, which is a collaboration platform specifically designed to embody the technological dynamics necessary to support the emergence of the 12 knowledge building principles. Their analysis found that while in theory all the 12 knowledge building principles are expected to be interrelated and mutually supportive of each other in their development, the emergence of these characteristics as evidenced through the Knowledge Forum® discourse was rather uneven. Further, they found a consistent trajectory in the emergence of these 12 socio-cognitive dynamics. Building on the earlier findings, this paper proposes a four dimensional model of assessing knowledge building outcomes based on the 12 knowledge building principles, and discusses how this model relates to the theoretical discussions and empirical findings in the CSCL literature reviewed (see Table 1 for an overview).

The first dimension is the presence of *a social dynamic conducive to sharing and open exploration of ideas*. This dimension relates to whether the social dynamics as revealed through the message contents is one that welcomes new ideas or conversely a social climate that squashes or puts down ideas (Newman et al. 1997). It reveals the level of achievement broadly within the first two phases in Gunawardena et al.'s (1997) Interactional Analysis Model (the sharing/comparing of information and the discovery and exploration of dissonance among ideas) or Soller et al.'s (1998) participation characteristic. The three knowledge building principles within this dimension (community knowledge, collective responsibility, democratizing knowledge and idea diversity) were found to be the earliest to emerge from data collected at an earlier study (Law & Wong, 2003). This can be interpreted as an affirmation of the importance of a conducive social dynamic as a pre-requisite for further knowledge building advances.

A second dimension of group outcome, *progressive inquiry orientation*, relates more closely to the critical exploration of ideas and progressive inquiry, involving the following four knowledge building principles : epistemic agency, knowledge building discourse, improvable ideas and constructive use of authoritative sources. There is a strong similarity between these principles with the characteristics found in phases of dissonance and co-construction of knowledge (Gunawardena et al., 1997) and with the indicators related to linking ideas, treatment of ambiguities, justification and critical assessment used by Newman et al. (1997). However, Scardamalia & Bereiter's (1991) theory of knowledge building requires that the members of a knowledge building community to set the advancement of knowledge as their explicit goal. This dimension thus also emphasizes on the sense of "agency" or intentionality of the members, and is close to two of Soller et al.'s (1998) characteristics of effective collaborative teams, social grounding and active learning conversation skills. Earlier analysis by Law & Wong (2003) found characteristics within this dimension emerge somewhat later and less effectively compared to those in the first dimension.

The third dimension is the *socio-metacognitive orientation* of the team/community, involving three knowledge building principles, real ideas, authentic problems, rise above, embedded and transformative assessment. It specifies that effective collaboration requires that members engage metacognitively with the inquiry task at hand, transforming authentic problems into researchable questions, formulating more inclusive, higher level conceptualizations as well as engaging continuously in internal assessment as a sustained effort to work at the cutting edge of knowledge. This is very similar to the formulation of the characteristic "performance analysis and group processing" in Soller et al.'s model while also bearing resemblances to some indicators in the other models as presented in Table 1. Characteristics within this dimension are not readily achieved and some groups did not exhibit any of these within the project life-cycle as reported by Law & Wong (2003).

The fourth dimension, comprising the principles pervasive knowledge building and symmetric knowledge advancement, describe characteristics of a community that has already internalized knowledge building as a collective "habit of mind" in that it is not an activity confined to particular occasions or subjects. Stahl (2002) commented that "*Collaborative knowledge building may be a way of life on the leading edge of scientific research, but it has proven devilishly hard to foster in contemporary school classrooms.*" (p. 63). It is perhaps not surprising that in Law & Wong's (2003) analysis, none of the groups exhibited characteristics indicative of these two principles. There are also no comparable indicators developed in other content analysis schemes in the CSCL literature.

Table 1. A categorization of Scardamalia's (2002) Knowledge Building Principles, Gunawardena et al.'s (1997) phase of knowledge co-construction, Newman et al.'s (1997) indicators for critical thinking and Soller et al.'s (1998) characteristics of collaborative learning teams into four dimensions of communal learning outcomes in knowledge building.

Dimension of community development	**Scardamalia's (2002) Knowledge Building Principles**	**Gunawardena et al.'s (1997) phase of knowledge co-construction**	**Newman et al.'s (1997) indicators for critical thinking**	**Soller et al.'s (1998) Collaborative Learning Model characteristics**
Social dynamic conducive to sharing and open exploration of ideas	• Community know- ledge, collective responsibility • Democratizing knowledge • Idea diversity	• Sharing/comparing of information	• Novelty • Relevance • Outside knowledge/experience • Importance	• participation • promotive interaction
Progressive inquiry orientation	• Epistemic agency • Knowledge building discourse • Improvable ideas • Constructive use of authoritative sources	• Discovery and exploration of dissonance or inconsistency of ideas • Negotiation/co-construction of knowledge • Testing/modification of proposed co-constructed synthesis	• linking ideas • treatment of ambiguities • justification • critical assessment	• social grounding • active learning conversation skills
Socio-metacognitive orientation	• Real ideas, authentic problems • Rise above • Embedded and transformative assessment	• Co-construction of knowledge/application of newly constructed meaning	• practical utility • width of understanding	• performance analysis and group processing
A communal "habit of mind"	• Pervasive knowledge building • Symmetric knowledge advancement			

Table 2. Scores for the mean group score[1] for each of the participating classes on the 4 dimensions of knowledge building learning outcomes based on a re-analysis of data presented in Law & Wong (2003).

Dimension of knowledge building outcomes	*Class A (43, 7)*[2]	*Class B (42, 7)*	*Class C (42, 7)*	*Class D (45, 8)*	*Class E (34, 3)*	*Class F (34, 6)*	*Class G (19, 4)*	*Class H (4, 1)*	*Overall Mean*
Social dynamic conducive to sharing and open exploration of ideas	2.05[3]	1.72	1.90	2.10	1.90	1.56	1.67	2.67	1.88[4]
Progressive inquiry orientation	1.21	0.93	1.18	1.38	1.50	0.71	1.50	1.50	1.17
Socio-metacognitive orientation	0.62	0.43	0.24	1.17	1.13	0.17	1.33	1.00	0.68
A communal "habit of mind"	0	0	0	0	0	0	0	0	0

[1] The maximum score for each principle is 3.
[2] The first number inside brackets indicates the total number of students in the class, and the second number indicates the number of groups in the class. The total number of groups participating in the project was 43.
[3] The contributions from each group was given a score for each principle, and the class mean score for each dimension was the mean score per principle within the dimension averaged for all groups within each class.
[4] The overall mean of each dimension is generated from the sum of means of the 43 groups divided by the total number of groups (43).

CSCL discussions are often used to support learning activities that are extended over periods of weeks or months, and it would be very useful if there can be simple tools for formative assessment of online discussions to help teachers in monitoring class progress and implementing suitable facilitation measures. Well designed assessment feedback to learners can provide a better understanding of what makes up a productive online discussion and scaffold collaborative learning. In our earlier work (Law & Wong, 1998), we observed a pattern in the trajectory of emergence of the knowledge building principles in the online discourse of around 250 students in 5 schools. Table 2 presents the re-analysis of that data into the four dimensions described above. The trajectory becomes even more distinctive and consistent.

CONCLUSION

This paper introduced a four dimensional model for the assessment of collaborative learning outcomes at the group/community level based on Scardamalia & Bereiter's (1991) theory of knowledge building built around a central concept of collective cognitive responsibility, compared the similarities of the model with several other models that describe outcomes or characteristics of collaborative teams based on learners' online discourse. It also reported on the findings from an application of the model to a large set of online discourse data which indicates that collaborative teams need to develop a social dynamic conducive to sharing and open exploration before significant progressive inquiry can take place. The findings also indicate that a collaborative team needs to develop a social-metacognitive orientation for knowledge co-construction and a communal habit of mind to advance in its knowledge building capacity. This model needs to be further tested against more extensive data of online knowledge building. It is also hoped that this model will provide a useful framework for assessment knowledge building outcomes at a team level as well as for the development of effective facilitation support to learners engaged in collaborative inquiry.

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Students Assessing Their Own Knowledge Advances in a Knowledge Building Environment

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Abstract. We describe the design of a knowledge-building environment and examine the roles of knowledge-building portfolios in characterizing and scaffolding collaborative inquiry. Three classes of Grade 9 students in Hong Kong used Knowledge Forum (KF) under several design conditions. Results showed (1) Students working on portfolios guided with knowledge building principles showed more participation, deeper inquiry and conceptual understanding than students working on KF only, or producing KF portfolios with no principles, (2) Students' knowledge-building inquiry and discourse were related to their conceptual understanding, and (3) Knowledge-building portfolios provided ways for identifying and characterizing collective knowledge advances in the community.

Keywords: Knowledge building, assessment, portfolios, inquiry, computer discussion forums

INTRODUCTION

There is now increased evidence of the cognitive benefits of computer supported collaborative learning. Research using asynchronous networked environments has shown how they help students advance understanding and inquiry, construct knowledge socially, and develop subject-knowledge understanding (CaMile, Guzdial, & Turns, 2000; Knowledge Forum, Scardamalia & Bereiter, 2003). Despite much progress, there remain questions regarding the integration of assessment, instruction and curriculum in CSCL classrooms, and specifically about the design of assessment to support and characterize learning and collaboration in classroom context.

Whereas networked computer discussion is becoming increasingly popular, many challenges and difficulties exist pertaining to the quality and variability in student participation (Hewitt, 2003; Lipponen, Rahikainen, Lallimo, & Hakkarainen, 2003). As well, there are issues concerning teacher assessment of students learning. Investigators have come to recognize that asking student to interact and discuss on computer forums does not necessarily lead to high-quality discourse. Hence the questions, How can students best learn about inquiry and collaboration when engaging in computer-supported discourse? How can classroom assessments tap into the theoretical nature of collaborative process while providing pedagogical support in scaffolding student understanding? This study examines the designs and roles of electronic portfolio assessments in characterizing and fostering collaborative inquiry in the context of Knowledge Forum, a computer-networked learning environment (Scardamalia & Bereiter, 2003).

Knowledge Building as Collective Cognitive Responsibility

In this paper, knowledge building is defined as "the production and continual improvement of ideas of value to a community" (Scardamalia & Bereiter, 2003, p. 1370) emphasizing 'improvable ideas' and 'collective cognitive responsibility." Similar to the process of scientific and scholarly inquiry, ideas are viewed as conceptual artifacts that can be examined and improved by means of public discourse within the knowledge-building community. In knowledge-building communities, students make progress not only in improving their personal but also in developing collective knowledge through progressive discourse. Knowledge building, according to Scardamalia (2002) may be summarized in a set of twelve knowledge building principles (i.e., epistemic agency, improvable ideas, community knowledge, diversity of ideas, rise-above, authentic problems, constructive uses of authoritative sources) identifying distinctive features and dynamics of the process.

To support working with knowledge, Knowledge Forum™ (KF), a web-based discussion forum, has been designed. A KF database is entirely created by students. Using networked computers, a number of users can simultaneously create notes (text or graphics) to add to the database, search existing notes, comment on other students' notes, or organize notes into more complex structures. The communal database serves as an objectification of the community's advancing knowledge. Features of KF are designed to help students reframe and advance ideas. For example, when writing a note in KF, students can add other notes as references, thereby creating an integrated web of notes (ideas) as their work proceeds. The visual linkages between ideas provide an important image for students, reflecting the interconnected and dialogical nature of knowledge that underpins the knowledge building perspective. Scaffolds or sentence starters such as 'My Theory' and 'I Need to Understand' are metacognitive prompts that can also be used to make the communicative intent of the information clear. For example, the scaffold 'My Theory' indicates that the information presented in the note is conjectural, and that it should be subjected to critique, testing, and application.

Learning, Assessment, and Collaboration

A major thrust of CSCL studies is quantitative and qualitative analyses of collaborative processes, and evaluation and assessment of systems and designs (e.g., Dillenbourg, Eurelings, & Hakkarainen, 2001; Stahl, 2001). Yet much less attention has been given to *formative, embedded, and transformative* aspects of assessment in collaborative inquiry, that is, how assessment can be used to *scaffold* students' collaborative inquiry and understanding. Analyses of computer discourse in computer networked environments and forums are common; current approaches focus on researcher-designed tools and analyses; but few are designed to provide *scaffolds* or to foster *agency* for students in CSCL classrooms. Despite the popularity of forums and networks, investigators have come to realize that putting students together does not mean they will engage in collaborative inquiry and deep discourse. Problems exist with low and variable participation rates and quality of discourse. In the following, we examine several issues about the alignment of learning, assessment and collaboration:

Assessment of Learning and Assessment for Learning

There have now been major shifts in paradigms of learning and instruction, and current views propose that assessment play the dual roles of scaffolding learning and measuring it (Bransford, Brown, & Cocking, 1999; Black & William, 1998; Gipps, 2002; Shepard, 2000). Assessments need to be designed so that they are parts of the instructional processes in fostering learning. The scaffolding aspect of assessment, sometimes called assessment *for* learning (Black & William, 1998), involves designing assessments in ways that foster learning. Despite major shifts in assessment reforms, little work has been conducted in aligning learning, assessment with collaboration in CSCL settings. Even though high-level goals are professed in computer-based instruction, when it is time for assessment, superficial knowledge is often emphasized (Chan & van Aalst, 2004; Reeve, 2000). Students need to be given the agency to assess their own and community knowledge advances. Assessment should be designed as a tool that both *measures* and *fosters* deeper inquiry and collaboration.

Assessment of Individual and Collective Aspects of Learning

Collaboration is valued in a wide range of social constructivist learning approaches, and there has been much research progress on collaboration (e.g., Koschmann, Hall, & Miyake, 2002). On the other hand, learning is nearly always evaluated at the level of individual learning outcomes in assessing the effectiveness of systems and designs (e.g., Dillenbourg et al., 2001). For example, Scardamalia, Bereiter, and Lamon (1994) emphasized a public knowledge building discourse. Yet they provided only assessments such as reading levels and depth of explanation at the individual differences level. This choice is problematic because when a theory is contributed to the public discourse and the community works on it, the theory no longer belongs just to the student who contributed it. It belongs to all in the community who worked on it. Students' individual learning attainments are important; however, there is a need to examine how we can assess *collective aspects* of knowledge advances.

Assessment of Content and Process.

Constructivist epistemology says that knowledge is constructed. If we want to prepare students for future learning—with less dependence on a teacher—we need to teach them to execute, monitor, and regulate the knowledge construction process. This would suggest that we must value not only what academic content is learned, but also how students achieve the learning. In higher education, there may be some emphasis on constructivist teaching and learning using asynchronous networked environments, but when assessment is carried out, primarily discrete knowledge and skills are considered. Even in more sophisticated environments involving peer learning, when group process is assessed, the assessment tends to focus on superficial features, such as whether students are contributing "equally" to the group work. We submit that assessment should tap both *collaborative process* and *knowledge products*.

Assessment of Knowledge Building and Portfolios

This study aims to examine the roles of student-directed portfolio assessment in characterizing and scaffolding collaboration and understanding. In the CSCL literature, there are several examples of student-directed assessment: self and peer-assessment in the SMART Environment (Vye, Schwartz, Bransford, Barron, Zech (1998), and reflective thinking in Thinker Tools (White, Shimoda, & Fredericksen, 1999). In our earlier studies, we have examined the use of student-directed portfolio assessments to characterize and foster knowledge building. We first designed knowledge-building principles and electronic portfolios for a graduate class (van Aalst & Chan, 2001) and further refined the designs in a Grade 12 classroom using communal portfolios (Chan & van Aalst, 2003). Students were asked to identify exemplary clusters of notes of their own and the class' best work and write a rise-above portfolio note referencing these notes and explaining the selection. We also examined individual knowledge advances using the notion of *depth of explanation* (Hakkarainen, Lipponen, & Jarvela, 2002). Students' participation in database usage (e.g., number of notes read, written, linked, revised) was assessed using server-log data with a programme called Analytic Toolkit developed by the Knowledge-Building Team (Burtis, 1998). Across different studies, we have found that portfolio scores were correlated with participation and conceptual understanding (Chan & van Aalst, 2003). Whereas portfolios commonly refer to individual's best work, we pioneered the notion of knowledge building portfolios for which students are asked to identify collective knowledge advances documenting the community's best work and progress.

The present paper continues this line of inquiry addressing the problem of assessing individual and collective knowledge advances in evaluating knowledge building. There are several refinements in our design: *First*, the earlier studies were conducted with graduate students and Grade 12 students in small classes. We want to examine, here, whether electronic portfolios can be extended to younger students in larger classes, thus exploring its value as a teacher assessment approach. *Second*, we earlier used four knowledge building principles for note selection; we now extend the use of knowledge building principles as scaffolds for student note writing as well as note selection. In particular, we ask students to write an essay on the basis of the portfolios thus investigating the relations between collaborative process and knowledge products. *Third*, our earlier studies included several components in the learning environment, and portfolio assessment was only one of them. Although it is typical of studies in technologically rich classrooms, the roles of knowledge-building principles and portfolios have not been specifically examined. In particular, it is not clear whether it is the portfolio task itself or the task augmented with the use of knowledge building principles that brought about the positive effects. This paper describes our refined design for knowledge-building portfolios. As well, we examine specifically several classrooms using Knowledge Forum (KF) only, KF with portfolios, and KF with portfolios guided by knowledge-building principles. While we recognize the complexity of classroom conditions, the comparison may help to illuminate the roles of knowledge building principles and portfolios.

In sum, the goal is to examine a knowledge-building environment using portfolio assessments for characterizing and assessing collaboration and conceptual understanding. There are several objectives: (1) To examine whether students using portfolio assessments with knowledge building principles showed more participation, deeper inquiry and conceptual understanding compared to their counterparts, (2) To examine different ways to assess knowledge building and investigate whether knowledge building inquiry and discourse are related to students' conceptual understanding, and (3) To examine how knowledge building principles and portfolios characterize and scaffold collective knowledge advances.

METHOD AND DESIGN

Participants

The participants were 119 students studying in four grade-nine Geography classes in a regular high school in Hong Kong, taught by the same teacher. Three of the classes were engaged in knowledge building using Knowledge Forum with different conditions. The fourth one was a comparison class that was not using KF; students in this class were required to submit a paper and pencil portfolio. The students at this school had high average abilities, they studied from English textbooks, and wrote in English on KF. Students were taught by an experienced geography teacher with over 12 years of teaching experience; he also had several years of experience using knowledge building pedagogy and Knowledge Forum.

The Classroom Setting

Knowledge Forum was implemented in the geography curriculum starting in the second semester for a period of three months. The teacher integrated knowledge building pedagogy with the school curriculum. A number of curriculum units were taught including "Ocean in Trouble", "Rich and Poor," and "Saving our Rainforests". Students were asked to discuss the topics on Knowledge Forum after school, and problems emerging in the computer discourse were discussed in class. Students in the comparison class also worked after school because they needed to submit a paper-and-pencil portfolio.

Design of the Learning Environment

The course was organized and informed by the knowledge-building pedagogy; students worked on Knowledge Forum as they generated questions, posed alternative theories and hypotheses, brought in new information, considered different students' views, and reconstructed their own understanding. Knowledge Forum was not used as an addition of computer software to the classroom activities; instead the knowledge-building principles and the work with Knowledge Forum were integrated with classroom instruction.

Developing a Collaborative Classroom Culture

Before the implementation of Knowledge Forum, students were provided with learning experiences acculturating them into the practices of collaborative learning. Such learning experiences are particularly important for Asian students who are generally more used to a didactic mode of teaching. Several group learning activities were included, for example, jigsaw learning and collaborative concept mapping.

Introduction to Knowledge Building and Knowledge Forum

Knowledge building was implemented in the three classes in early February. The teacher created a view called "World Problems and How to look after the World" that was used as the focal problem. Three sub-views were included: "Rich and Poor", "World Oceans", and "Tropical Rainforests" that link up the fragmented topics of the textbooks to allow for sustained inquiry. Typically the teacher wrote an introduction that explains the purposes of each view. As with other knowledge-building classrooms, students posed questions and problems; they made conjectures, examined different explanations, revised their 'theories' as they examined each other's KF notes.

Deepening Knowledge Building Discourse and View Management

As the number of notes increased with time, teachers worked with students and identified sub-themes and created *rise-above* views. Clusters of notes were grouped, and key issues highlighted with the class. Students were also asked to pose 'rise-above' notes. View maintenance and continuous updating of views in the database made it easier for the community to identify the focus and themes of notes. Student could see more easily what was current in the views and focus their reading and writing.

Embedded and Concurrent Assessment Using Knowledge Building Portfolios

After the introduction of Knowledge Forum and some initial work, there were differences in instruction: Whereas students in the "KF class" continued to engage in KF discussion only, students in "KF with portfolios class" were required to submit an electronic portfolio with a selection and explanation of four clusters of good discussion notes in the database. Students in "KF with knowledge-building portfolios class" also needed to do this task, but they were provided with a set of knowledge-building principles as scaffolds in note writing and note selection (Table 1). Based on Scardamalia's set of knowledge-building principles, we have developed a smaller set designed for use as pedagogical and assessment tools. We adapted the guidelines from earlier studies, so they could be more accessible to middle-school students.

A brief description is given for the knowledge-building principles (for details, see Chan & van Aalst (2003): (1) *Working at the cutting edge.* This principle is related to epistemic agency, and it is based on the idea that a scholarly community works to advance its collective knowledge. For example, scientists do not work on problems of only personal interest, but on problems that can contribute something new to a field. (2) *Progressive problem solving*. The basic idea is that when an expert understands a problem at one level, he or she reinvests learning resources into new learning. In the scholarly community, we often find one study raises new questions that are explored in follow-up studies. (3) *Collaborative effort.* This principle focuses on the importance of working on shared goals and values in developing community knowledge. (4) *Monitoring personal knowledge*. This principle is based on the idea that metacognitive understanding is needed for knowledge-building work. Specifically, it requires students to have insight into their own learning processes. It is similar to progressive problem solving in that it documents the history of ideas or problems--but now the focus is placed on metacognitive processes. (5) *Constructive uses of authoritative sources*. This principle focuses on the importance of keeping in touch with the present state and growing edge of knowledge in the field. To make knowledge advancement requires making references, building on, as well as critiquing authoritative sources of information.

Data Sources

Analytic Toolkit and Database Usage

The Analytic Toolkit (ATK, Burtis, 1998) provided an overview of student participation using information on database usage. Several quantitative indices include: (a) Number of notes *written*, (b) Number of notes *read*, (c) Number of *scaffolds* used; scaffolds are thinking prompts (e.g., I need to understand) to guide writing and collaboration, (d) Number of notes *revised*; revision is an important metacognitive process; (e) Percentage of notes *linked* to other notes, and (f) Percentage of notes with *keywords* that can help others to search the notes.

Table 1. Teacher Guidelines on Knowledge Building Principles and Portfolios

You need to select four best clusters of notes together with a summary note that explains why you have selected the notes. Use the principles and criteria to help you with note selection.
Principle One: Working at the Cutting Edge • Identify knowledge gaps, inconsistencies and ask productive questions • Pose problems that extend the edge of understanding of the community • Pose problems with potential for continual discussion and inquiry (i.e., interest many people)
Principle Two: Progressive problem solving • Show continual efforts to grapple with problems posed by classmates • Pose notes aimed at addressing the original problem and questions arising from them • Show sustained inquiry: Identify the problem, solve the problem, but keep asking new questions • Reinvest efforts to keep solving new problems to improve ideas
Principle Three: Collaborative Effort • Use various KF functions such as references and rise-above to make knowledge accessible • Summarize different ideas and viewpoints and put them together as a better theory • Help classmates to extend and improve their understanding • Encourage classmates to write notes that follow the other principles
Principle Four: Monitoring Own Understanding • Explain what you did not know and what you have learned • Recognize discrepancies and misconceptions and new insights; trace own paths of understanding • Show your new ways of looking at things (questions, ideas, issues) after examining other KF notes
Principle Five: Constructive Uses of Different Sources of Information • Use information from other sources (Internet, newspaper…etc) to support or explain your ideas • Bring together classroom learning, information from textbook, classmates' KF notes • Provide contrasting or conflicting information to what is printed in the textbook

Depth of Inquiry and Depth of Explanation

Computer notes consisting of responses and questions were examined for assessing knowledge-seeking inquiry, based on earlier research on depth of explanation (Hakkarainen et al., 2002). Students' responses were coded on a 7-point scale to distinguish the levels of depth of inquiry, and students' questions were coded on a 4-point scale (Chan & van Aalst, 2003). These levels ranged from fragmented responses to paraphrasing information to inferences to explanatory inquiry.

Knowledge Building Portfolios

Students were asked to prepare a portfolio of four clusters of notes in which they provided evidence for knowledge-building principles (i.e., cutting edge, progressive problem solving, collaborative effort, monitoring own knowledge, constructive uses of resources). In their selection, they needed to include their own notes as well as others' notes in the database. They also needed to write an explanatory statement for each cluster on why these notes best demonstrated evidence of knowledge building. Portfolios were coded on both explanation and evidence of knowledge building on a 6-point scale.

Conceptual Understanding

To assess students' conceptual understanding of the domain in question, students in all classrooms were administered the following writing task: *"We have been exploring three major world problems, namely 'Rich and Poor', 'Ocean in Trouble', and 'Deforestation'. In not less than 300 words, express your view on the following question: Who and how should we look after the World?"* Students' responses to the writing task were coded using rubrics and schemes regularly used in the school.

RESULTS

Class differences on participation, collaboration and conceptual understanding

Participation and Collaboration Shown on Database Usage

We first examined students' overall participation and collaboration based on database usage on Knowledge Forum. The general descriptive picture from Analytic Toolkit indicated a sizeable usage of the databases: There were totals of 661, 302, and 1090 written notes, respectively, contributed by the three classes (KF, KF with portfolio, and KF with knowledge-building portfolio). The average number of notes written were 16, 8, and 27 for the three conditions, respectively, in a 3-month period. To simplify presentation, the ATK indices were combined using factor analyses: Factor One called *ATK Knowledge Building Inquiry Index* (i.e., write, read, scaffold) explained 42.6% of the variance, and Factor II called *ATK Knowledge Building Visual Organization* Index (i.e., keyword, link) explained 10.1% of the variance. ANCOVA analyses controlling for differences in academic achievements showed that students in different design conditions had different participation scores, $F(2, 113) = 7.31$, $p<.001$. Table 2 shows that KF class with kb portfolios had a higher ATK Inquiry index than Knowledge Forum (KF) class, and KF class with portfolios scored higher on Inquiry Index than KF class. There were no significant differences for the Visual Organization index.

Depth of Inquiry and Depth of Explanation

The entire set of computer notes including questions and responses were scored. An overall weighted score called *Depth of Inquiry* was computed based on quality and frequency of questions. ANCOVA analyses controlling for differences in academic achievements showed that KF with kb portfolios class had significantly higher mean scores than the other two classes, $F(2, 113) = 9.23$, $p<.001$ (Table 2). Students' written responses were also scored and computed to obtain an overall weighted score called *Depth of Explanation*. ANCOVA showed that KF with kb portfolio class had a significantly higher mean score than KF with portfolio class, $F = 3.98$, $p = .021$ (Table 2). These results suggest that students scaffolded with knowledge building principles and portfolios participated more, and they produced deeper questions and explanations.

Conceptual Understanding

The means of conceptual understanding scores based on a writing task were 5.5 for no KF class, 5.2 for KF class, 5.2 for KF class with portfolios, and 7.0 for KF class with knowledge-building portfolios. ANCOVA analyses indicated that significant differences were obtained favoring KF with knowledge-building portfolios over other classes, F=6.6, $p<.001$.

Table 2. Scores on Participation, Inquiry, and Explanation Across Design Conditions

Class	KF		KF with Portfolio		KF with portfolio and principles	
	M	SD	M	SD	M	SD
ATK Inquiry	-.45 b	.37	.03 a, b	.83	.44 a	1.2
ATK Visual Organization	-.17	.82	.01	.96	.18	.92
Depth of Inquiry	1.85 a	1.34	2.24 b	1.33	3.59 a, b	1.6
Depth of Explanation	3.55	1.21	3.01 a	1.25	4.33 a	2.15

Note: Means in a row sharing subscripts are significantly different. $p<.01$.

Relations among Participation, Inquiry and Conceptual Understanding

We examined the relations between students' ATK participation and depth of inquiry with their conceptual understanding for all students working on KF. We used students' scores on Hong Kong Attainment Tests as covariates, controlling for the effects of academic achievement. Participation was measured by ATK with the two factors of Inquiry and Visual Organization. Depth of inquiry was assessed by students' weighted scores on questions and responses. Correlation coefficients show that ATK Inquiry Index, was significantly correlated with Depth of Inquiry (r=.39, $p<.001$), Depth of Explanation (r=.35, $p<.001$) and writing (r=.16, $p<.05$). ATK Visual Organization Index was significantly correlated with the Depth of Inquiry ($r = .48$, $p<.001$) and Depth of

Explanation (r = .27, p<.05). Both inquiry and explanation scores were correlated with writing (r = .20, p<.01). These findings show that participation on KF and depth of inquiry were related to conceptual understanding.

Table 3. Correlations among Participation, Inquiry and Conceptual Understanding

	ATK inquiry	ATK visual organization	Depth of inquiry	Depth of explanation
ATK visual	.52***			
Depth of inquiry	.39***	.48***		
Depth of explanation	.35***	.27**	.27**	
Writing	.16*	.02	.20**	.20**

Note: *p <.05; **p < .01; ***p < .001

Relations among Participation, Inquiry, KB Portfolios and Conceptual Understanding

We also examined the relations between students' knowledge building portfolio scores with other measures for the KF with kb portfolio class (n=29). We used scores on Hong Kong Attainment Tests as covariates controlling for the effects of academic achievements. The knowledge building portfolios were rated on a 6-point scale both on the explanatory statements and the selection of notes. Knowledge building portfolio ratings were significantly correlated with ATK Inquiry (r=.35, p= 08). As well, knowledge building portfolio ratings were significantly correlated with essay writing reflecting conceptual understanding (r=.37, p=.066), both at .10 level. Students showing more evidence of knowledge building in their portfolios scored higher on conceptual understanding.

Characterizing Individual and Collective Knowledge Advances

Students were asked to produce four clusters of notes with explanations in their portfolios. Two examples are provided here to illustrate the differences of portfolios with and without principles. As well, the portfolio note guided by knowledge-building principles helps to characterize individual and collective knowledge advances.

Figure 1. A portfolio note illustrating a knowledge-building principle and collective knowledge advances

The Theme of the Discussion The effects of chemicals on the oceans…. It began with the question "Do shipwrecks [such as] the Titanic add pollution to the world' s oceans?"***My Interpretation*** **At first, I thought that my question was quite debatable[1] . But in the end, I still thought that shipwrecks weren't as harmful as they seemed to be**. I thought that after decomposition of oil spills, the oceans could return to their initial form, **but this idea was heavily criticized by my classmates.** They all thought that shipwrecks brought serious threats to the oceans[2] [3] . …They said that if oil was spilt into the oceans, it could kill many animals before the oil could be decomposed. Mr. Lee told us that if a certain species is killed, it might break the food chain. Therefore, oil spills are quite dangerous to our oceans. **I was [shown] that oil spills were far more serious than I ever expected**. Then, CW corrected a stupid mistake that was made by me. He told me that the Titanic ran on coal, not on oil. Therefore, I realized that I actually had a problem with my question. T**hen, the first evolution came. ER suddenly asked if the oil from an oil spill is an ocean resource**[4] . Naturally, CW answered this question[5] . **Here's the second evolution. CY started to argue that tankers carrying chemicals are more dangerous than oil tankers**[6] , CW and I didn' t agree though[7]. We thought that although cyanide is more poisonous than oil, cyanide is soluble in water. Therefore, its effects on the oceans are less than those of oil[8] . WY agreed with this [9] , SL too. He said that oil is difficult to clean up, and could kill heaps of wildlife, **but I still had my questions... Are oil spills really that bad to the oceans?** After 50 years or so, the oil would start to decompose and the corals would grow on the shipwreck, it' d become an artificial reef, what' s the problem with that[10]?CW agreed with me that shipwrecks aren't really that bad in the long term *"water wave will wash the oil and make them into smaller particles and decompose them in the following years!"*[11] **TY also pointed out that pollution is proportional. Oil spills could help the environment-- *"the resources used up " and the curve of the pollution is proportional. So if we can control the use the resources , we can also reduce the level of pollution ~"*[12]** ***Principle 2 Improvable Ideas/Progressive Problem Solving*** I [think] that this is a principle 2 note because in this cluster of notes, **many new and improved questions have evolved from one simple note in the beginning.** ***Reasons*** **In the beginning, I was asking about shipwrecks, soon the discussion turned to chemicals and finally a new concept was pointed out (pollution is proportional). Every time there was a question, we'd solve it, think of another question and solve that as [we] get better answers and more questions.**

Note: The number in superscripts are computer notes in the databases included as reference notes

Figure 1 shows an example illustrating how portfolios might help to identify and characterize knowledge-building episodes in the community, and how they scaffold the student's reflection and understanding. At the beginning, Student A referred to a question he had posed, "Do shipwrecks add pollution to the world's oceans ?" Instead of asking a typical textbook question, Student A posed what might be called an authentic problem with potential for inquiry (Scardamalia, 2002). Student A identified diverse ideas from his classmates and explained how they differed from his views. In examining the discourse, Student A also became more aware of the 'mistakes' (misconceptions) he had (Titantic used coal not oil). The portfolio note illustrated how the students worked collaboratively on the problem, pushing for new understanding, rather than having premature closure.

As they pursued the problem, Student A wrote that he had the 'first evolution' [insight] when someone asked whether an oil spill can be a resource. He then described another evolution when the classmates discussed whether oil spills or chemical pollutions are more serious. Further inquiry of the problem led to improved ideas and new realizations – proportionality and control of resources as ways to control pollution. The portfolio note helps demonstrate that knowledge building involves a problem-centred collaborative inquiry process where new ideas are examined, debated, and improved upon. As the student explained, "At first, I was asking about shipwrecks, soon the discussion turned to chemicals and finally a new concept was pointed out (pollution is proportional). Every time there was a question, we' d solve it, think of another question and solve that as well to get better answers and more questions."

Figure 2. An example of a portfolio without knowledge-building principles showing shallow discourse

This topic is ocean in trouble. The question is *"Oil spill is a kind of pollution. But where does it come from? From an accident of a ship or from nature?"*[1] This is a simple question, I don' t think nature can make oil spill occur. [2] [3] [4] **These three notes have answered the big question of oil spill**. Oil [comes] from the ground and [it is] transported by ship. But some accidents have happened [and] the oil spills on the surface of ocean. Oil spill is a serious problem of pollution; it kill[s] the marine wildlife and make[s] the world problem [creating] lack of fishes. The other most interesting note comes from *"Why a small amount of oil will be formed when it is raining? "*[5] Before I see this note, I don' t know the rain contains oil, I think this is silly to say "Oil Rain!".There are three answer[s] to the notes, that include:*" Internet says that the rain may contain a small amount of oil."*[6] *", the car fumes contain some toxic chemicals, and a little amount of oil may still be in the smoke. So, the smoke goes up and [gets into] the rain. "*[7] and *"the soil is fat and may contain oil, so when rainwater come through, oil may [be] flushed away with the rainwater..."*[8] **I think the acceptable answer is [that] smoke with water vapour is absorbed by the Sun, and [it]condenses to from cloud [and] finally forms rain.**

Note: The number in superscripts are computer notes in the databases included as reference notes

We provided an example of a different kind of note when students also found exemplary notes from the class on the same theme without having been given the scaffolds of the knowledge-building principles. In this example, the selection of question is different: Student B identified a note that asked quite a general question - where does an oil spill come from? He then wrote he found three notes that answered the question and the problem was considered solved. The same situation occurred again – This time the question was more interesting but Student B still used the strategy of finding three notes that answered the question and found the most acceptable one. The notion of improvable idea or collective advances cannot be found in this note. Instead the student seemed to be more engaged in a form of premature closure focusing on finding the correct answers.

DISCUSSION

We have described a knowledge-building environment augmented with the use of portfolios and knowledge-building principles to characterize and scaffold collaborative inquiry. Primarily we turned over agency to students, asking them to assess their own and the community's knowledge advances in the computer discourse, using an electronic portfolio. We extended our earlier work from graduate students and senior-secondary students to middle-school students in large classes. We used knowledge building principles more intensively as both note writing and note selection guidelines. The findings show that students provided with knowledge-building principles as scaffolds participated more and engaged in deeper inquiry. Consistent with our earlier work (Chan & van Aalst, 2003), knowledge building activity was related to students' conceptual understanding.

Knowledge Building Portfolios as Scaffolds for Collaborative Inquiry

We first examine the roles of knowledge-building principles and portfolios and consider how they may scaffold collaborative inquiry. In this study, we had several design conditions. The results showed that student provided with knowledge-building principles participated more and engaged in deeper inquiry than their counterparts. A system of knowledge-building principles was postulated by Scardamalia (2002) for theorizing the dynamics and processes of knowledge building. Thus far, researchers used the framework of knowledge building principles to analyze the databases. We adapted the principles and turned over to students the responsibility for identifying knowledge-building episodes in their computer discourse. In doing that, knowledge-building principles become not just analysis tools, but pedagogical and assessment tools for scaffolding knowledge building. We propose that when students work on identifying knowledge building episodes, the principles can be a form of scaffold that helps them recognize what constitutes productive discourse. As they see different models, they would be able to move towards producing better notes and engaging in deeper discourse. Protocol examples indicated that Student A was able to use the principle 'progressive problem solving' to explain how ideas evolved and improved over time. By contrast, Student B was merely identifying good answers to questions classmates posed. Without knowledge-building principles or other criteria, students could easily see collaboration as discussion and producing good answers. That may explain why many students are reluctant to participate in discussion on networked environments. Knowledge building principles as scaffolds may help students understand what constitutes progressive discourse. As the goal of knowledge building is improvable ideas (Scardamalia & Bereiter, 2002), we made that explicit to students; then that could become a goal of the community.

Alignment of Learning, Assessment and Collaboration

We have designed an environment that was intended to address certain gaps for designing assessment in CSCL classrooms. Earlier, we noted three of these issues: Assessment of learning versus assessment for learning, assessment of individual and collective advances, and assessment of processes and content. *First*, the knowledge building portfolios play dual roles of characterizing and fostering collaboration. Commonly, assessment is concerned with analyzing the collaborative process or evaluating what students have learned. Knowledge-building portfolio assessment is designed so that self- and peer-assessments foster inquiry and understanding. As shown above (Figure 1), in identifying exemplary clusters of notes and providing explanations, students must browse through the database and synthesize their own and collective understanding. Fragmented understanding, scattered discussion, and superficial work might be avoided. The assessment approach examines collaboration as well as provides a tool for deepening inquiry. *Second,* this study included several measures (e.g., ATK, depth of inquiry) to assess knowledge building. Specifically, we designed knowledge-building portfolios that capture both individual and collective aspects of knowledge building. As shown in the portfolio example (Figure 1), the student was not merely describing his personal work; he was describing how a problem was addressed by a group of students, what views they held, what misconceptions were identified, what critical incidents took place, and how the idea was gradually improved. Knowledge building postulated by Bereiter and Scardamalia (2002) is analogous to scientific inquiry in scholarly and scientific communities. Even middle-school students can be engaged in a process similar to the writing of scholarly reviews when someone integrates differing ideas/studies to provide the 'state of knowledge' for a certain problem/theme. Knowledge-building portfolios capture both collective knowledge advances as well as students' growth in understanding. *Third*, the portfolios showed that content and process were both assessed. The portfolio example illustrated how students were engaged in progressive problem solving (see Figure 1); it also provided rich information about how they have gained subject-matter knowledge (e.g., oil spills as resources, proportionality, control of resources).

It may be useful to note the limitations of this study. Due to the complexity of classroom life, comparison of design conditions across classrooms necessarily faces many problems common in technology studies. Whereas the quantitative findings are included, caution needs to be exercised in interpreting them. These different design conditions, however, help us to understand more fully how knowledge building works. We also emphasize examining portfolios can help characterize and assess both individual and collective understanding. Ongoing analyses and inter-rater reliability are being conducted. In terms of pedagogical implications, earlier we noted problems and challenges of low and variable participation rates and problems with teacher assessment. The portfolio approach may be a way to address the problems, in that students need to write some notes before they can have enough notes to do the portfolios. Or at least they would need to do substantial reading of others' notes when putting together the portfolios. We also noted the problems of teachers having difficulties with reading hundreds or even thousands of notes. The two-pronged approach of Analytic Toolkit providing an overview as well as the portfolios--a synthesis of what goes on in computer discourse-- can help teachers recognize and assess overall participation as well as critical incidents of knowledge building in the community. They would be able to identify areas where students may have problems and what progress they have made.

In sum, we have extended our earlier work examining portfolio assessments and demonstrated more clearly the roles of knowledge building principles. We propose that when students are provided with the principles, they can become more aware of what productive discourse entails; the principles are scaffolds for their knowledge-building progressive inquiry. As well, students are not merely focused on their own work, they are engaged in characterizing the community's best work and progress. Our approach of making knowledge building explicit to students is consistent with current emphasis on alignment of learning with assessment (e.g., Shepard, 2000). We have extended the idea of portfolio as assessing individual to community progress and demonstrated how knowledge-building portfolios may characterize and scaffold collective knowledge advances.

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Vulgar competence, ethnomethodological indifference and curricular design

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Abstract. In the paper, we discuss the relation between ethnomethodologically inspired video analysis and curricular design. Often the relation between analysis and design is taken as a relation between descriptive and prescriptive accounts. Conceptualised in this way, ethnomethodology and curricular design is a world apart. With a focus on ethnomethodology's take on analytical and normative questions, however, some ethnomethodological insights might play an interesting role in investigation as well as development of computer based learning environments. The discussion is structured around four analytical commitments: become vulgarly competent; be indifferent to formal analytic methods, not member concerns; focus on actions and immanent pedagogies, not learning; and, do hybrid studies.

Keywords: Ethnomethodology, video analysis, conversation analysis, design experiments, methodology

INTRODUCTION

The last years growing interest in *designed based research*[1], has partly developed as a response to the limitations of using standardized tests in order to investigate educational interventions (e.g., The design-based research collective, 2003). As Berger *et al.* (1994) puts it "even the best pre-post and randomized designs" (p. 476) cannot provide an "understanding of what is going on while students are learning using instructional technology" (ibid.). Recognizing this problem with most studies of computers in education, Roth *et al.* (1996) argue for a methodological change: from treating the technological interventions as independent variables or factors to approaches where students' interaction with technology is investigated. Such an approach also concurs with the growing recognition that general statements about technological or curricular interventions seldom are functional if one wants to understand and further improve educational activities. As Erickson (1986) points out:

> Answering the question, "What is happening?" with a general answer often is not very useful. "The teacher (or students) in this classroom is (are) on-task" often doesn't tell us the specific details that are needed in order to understand what is being done […] Nor is an answer like the following sufficient usually: "The teacher is using behavior modification techniques effectively." (p. 121)

Erickson continues by arguing that questions concerning how the teacher use the techniques and what these techniques consist of are potentially more rewarding than general questions. This makes him draw the somewhat paradoxical conclusion that "to achieve valid discovery of universals one must stay very close to concrete cases" (p. 130). In line with this, our research group have increasingly been concerned with the relation between theory and practice; or, to be more precise, between video-analysis and curricular design. Two questions have recurred, in different guises, in discussions with colleagues, teachers and students: in what way can one perform investigations that are *useable* in the development of learning environments and how can the development and assessment of educational settings *inform* our research? Although the relation between descriptive studies and design has to be dealt with in relation to each particular project, we hold that issues concerning analytical commitments, normativity and relevance have consequences for both research and curricular design. Furthermore, we believe that ethnomethodology (EM), by its focus on the practical details of interaction and interest in the reflexive relationship between competencies and settings, has a take on these issues relevant to the CSCL community.

EM, CA and hybrid studies

Beginning in the 1950's, EM has its roots in the work of Harold Garfinkel and has subsequently developed and diverged into rather different strands of research (Maynard & Clayman, 1991). In an often-recounted story, Garfinkel coined the term ethnomethodology when he, together with other researchers, was to investigate the work and reasoning of juries (cf. Garfinkel *et al.*, 1981; Heritage, 1984; Hill & Crittenden, 1968). To borrow a phrase from Hutchins (1995), the researchers tried to investigate reasoning "in the wild" by analyzing tape recordings of jury deliberations from an actual case. Instead of using predefined categories, such as Bales Interaction Process Analysis (Bales, 1950)[2], Garfinkel was interested in capturing the particular (ethno)methods through which the jury was constituted and made recognizable *as* a jury. A fundamental premise in this research – and arguably the most fundamental assumption in all EM research since then – is that social action are produced and recognized in orderly and intelligible ways since members of a setting have recognizably shared methods for producing action. How members' methods create order are therefore to be found in witnessable interactional details; and, consequently, the production of order can be discovered if a researcher conducts close investigations of practical activities[3].

In the sixties until the mid seventies, Garfinkel was collaborating with Harvey Sacks, the initiator of conversation analysis (CA). By transcribing and thoroughly examining tapes of ordinary conversations, Sacks and colleagues – such as Gail Jefferson and Emmanuel Schegloff – developed an approach to the study of naturally occurring conversation, focusing on the sequential organisation of talk-in-interaction. Ground breaking studies was provided regarding structures such as *turn-taking* (Sacks *et al.*, 1974), *adjacency pairs* (Schegloff, 1972; Schegloff & Sacks, 1973) and *repairs* (Schegloff *et al.*, 1977). Nowadays, many researchers consider CA an established academic discipline and the research program has accumulated a large body of studies (for overviews, see: Goodwin & Heritage, 1990; Hutchby & Wooffitt, 1998; Psathas, 1995; Silverman, 1998; ten Have, 1999). Studies conducted in the tradition of Jefferson and Schegloff are often concerned with interaction sequences regardless of the particular setting examined, "whether it be the home, the laboratory, the office or the street" (Psathas, 1999, p. 141). This could be seen as a consequence of the attempt to find as high a level generalisation as possible concerning the role and significance of particular practices of interaction.

Although CA might be the most successful offspring of EM, a growing number of studies have focused on the particularities of interaction in organizational environments such as the laboratory or the office (e.g., Goodwin, 1995; Heath & Luff, 1996; Luff & Heath, 1993; Suchman, 2000; Whalen, 1995). There are also EM studies that have investigated the particularities of a range of educational settings. In the introduction to a edited book, Hester and Francis (2000) classify studies of "local educational order" in six categories, for instance, studies of educational decision-making or studies occupied with classroom control and the identification and management of deviance. For our purposes, the studies mentioned in connection to Hester and Francis' fifth theme, studies concerned with the organisation and accomplishment of academic knowledge, are of particular interest since they carefully examine how competencies are made visible as the relevant business of the setting, a topic potentially rewarding to the analysis of computer supported learning environments.

Among the researchers "in this relatively neglected area" (Hester & Francis, 2000, p. 10), one can find Garfinkel and a few of his second generation of students and collaborators such as Lynch (Lynch & Macbeth, 1998) and Livingston (1986, 1987). These researchers, as well as some researchers within the field of CSCW (e.g., Button & Dourish, 1996; Crabtree, 2001), have begun to use the notion of *hybrid studies* to characterise their work. In an introduction to a recent book by Garfinkel (2002), Rawls claims that hybrid studies can be seen as a kind of "practical or applied research […] done by outsiders who are also insiders" (p. 40), with the aim "that practitioners in the specialty area being studied will be as interested in the studies as professional sociologists" (ibid.). Thus, although EM traditionally have been categorised as social science proper, hybrid studies are applied social science since such studies directly address practitioners. In the same book, Garfinkel maintain that hybrid studies "are written to be read alternately and interchangeably as descriptions and instructions" (2002, p. 102). This could be seen as contrasting with a claim made by Koschmann *et al*. (2004), in a paper that discuss ethnomethodologically informed video analysis[4], who maintain that EM "are purely descriptive and cannot be used to form prescriptive judgments" (p. 4). As we see it, however, the seemingly conflicting statements do not necessarily have to be opposed. From Garfinkel we take that hybrid studies should be instructive and usable to practitioners in the specialty area. Koschmann *et al*'s statement could be seen as pointing to the problem of transforming EM studies into simplified guidelines – or into the characteristic "implications for education" section in the end of otherwise descriptive articles[5] – and treat these transformations as EM. As we see it, the often-used distinction between description and prescription might actually hide the particular ways EM could be used in educational research.

Before we proceed with the discussion we want to point out that the goal is not to provide a reading of what the ethnomethodological program *really* means. Instead, we focus on insights that could be furnished to the particular demands of research aimed toward the development of education practice. Although we thereby discuss what Wilson (2003) call "soft ethnomethodology", we still think it can be rewarding to explore some of the more radical tendencies inherent in EM. The discussion of these matters take the form of four analytical commitments: *become vulgarly competent*; *be indifferent to formal analytic (FA) methods, not members concerns*; *focus on instructed action and immanent pedagogies, not learning*; *do hybrid studies*. The commitments are to be taken mainly as summaries of (or glosses on) one way EM could be used in educational research. There is an internal order among them, where each commitment builds on the previous and where they – in an indirect way – point towards different phases or activities within the research process.

BECOME VULGARLY COMPETENT

The first analytic commitment is to become vulgarly (ordinarily) competent in relation to the phenomenon or practice under scrutiny. For instance, Garfinkel insisted that his students, who set out to investigate specialized professional domains such as science, truck driving and mathematics, had the appropriate training in the practices of their fields of study. At first glance, this commitment could be seen as trivial. Of course the analyst has to have an understanding of the investigated phenomena. As Rawls (Garfinkel, 2002) points out, however, many researchers put more emphasis on formulating research questions, clarifying concepts and operationalizing terms than getting an initial understanding of the setting. Additionally it is often seen as unscientific "to change the research question, or research protocol, in the midst of research" (p. 27), with the consequence of "treating a researcher's increasing understanding of a research site as 'subjective,' while research conducted in relative ignorance is considered 'scientific'" (ibid.)[6].

The research projects we are involved in deal with settings that are highly specialized. For instance, in one project we are investigating the use of simulations by nurses who are training to be specialists; in another project we are looking at how engineering students perform lab work. In all projects, we investigate practices where members are supposed see certain things in professionally accountable ways: the nurses are supposed to see a high pulse rate as an indication of pain and act accordingly, and the engineering students have to be able to see a cluster of points on a computer screen as a relation between force and acceleration. In order to recognize what an event is, that is, what it is *heard* and *seen as*, by members to the setting studied, we as researchers have to be vulgarly competent in the work of the setting. Put differently, as any formulation made by a member means more than can be said in so many words (Garfinkel & Sacks, 1970), how a formulation is presumably heard is for its recognition tied to being a competent member of the setting studied. For competent members, formulations and activities make sense, but for a newcomer to a specialized setting it is impossible to fully grasp what is going on. As Lynch (1993) points out:

> As should be obvious to anyone who has attempted to read specialized scientific journals, a mastery of disciplinary techniques is required for making adequate sense of the prose, graphics and mathematical expressions. To comprehend the unique 'what' at the core of each coherent discipline requires a reciprocally unique method for coming to terms with it. Such method is inseparable from the immanent pedagogies by which members master their practices. (p. 273)

If video-analysts want to understand the practical competencies of anaesthesiologists or scientists in *interactional detail* it is not enough to have a general idea of what anaesthesiology, physiology or science is about; it is not enough with a "layman's gloss" (which we could gain simply by asking a member or reading a popular textbook on the subject). When Lynch writes about the reciprocally unique methods for coming to terms with the specific "what" at the core[7] of each discipline, he touches on a critical and distinctive aspect of EM: methods – any methods, be they methods of scientific practice or of ordinary rationality – are in each case locally occasioned and bound to a specific competence system (Lynch, 1993). This idea has sometimes been formulated as the unique adequacy requirement of method which:

> is identical with the requirement that for the analyst to recognize, or identify, or follow the development of, or describe phenomena of order* in local production of coherent detail the analyst must be *vulgarly* competent in the local production and reflexively natural accountability of the phenomenon of order* he [or she] is "studying" (Garfinkel & Wieder, 1992, p. 182) [8]

The unique adequacy requirement could be seen as an alternative to approaches that focus on generic theories, abstract models or underlying structures. The focus is on the particular, the specific and the ordinary. This requirement also have the consequence of making each area of investigation unique, and the whole corpus of ethnomethodological studies highly diverse, since the "the commitment to 'real worldliness' of phenomena means that how studies are done and presented is (should be) shaped by the distinctive character of the phenomena under investigation." (Hester & Francis, 2000, p. 4). The commitment to the "real worldliness of phenomena" is intrinsically bound to another commitment, the indifference to formal analytic methods, which will be dealt with in the next section.

BE INDIFFERENT TO FORMAL ANALYTIC METHODS, NOT TO MEMBERS CONCERNS

According to the policy ethnomethodological indifference, no set of standardized rules from the social, behavioural or natural sciences can be seen as operating *behind* those methods that members recognizably use. What is specific for EM is the way formal analytic methods of science used in *classical studies*[9] – such as modelling and coding – are given no privilege in relation to the methods under investigations. This stands in sharp contrast to much educational research were models and theories of learning often are seen as necessary components in doing investigations. The exercise of ethnomethodological indifference could therefore be seen as a way of abstaining from applying "a gratuitous 'scientific' instrument: a social science model, method, or scheme of rationality for observing, analyzing, and evaluating what members already can see and describe as a matter of course" (Lynch, 1999, p. 221). This does not mean that there is no difference between practitioners and the ethnomethodologist or that the analyst is indistinguishable from other competent participants in a particular activity. In contrast to practitioners, the ethnomethodologist are doing studies with the goal of making the results:

> tutorially available to staffs of order production [i.e., members of that particular discipline] as a descriptive/pedagogic order of argument without incongruities, absurdities, without errors of worldliness or facticity, without gaps, omissions, hiding out, faking, or changing the subject; but before everything else, for the work-enhancing edification that the local production staff whose work it describes demands independently of and indifferent to whether staff can prespecify those demands as a condition for making them (Garfinkel, 2002, p. 266).

In place of imposing theory and scientific method, EM studies tries to recover the endogenous rationality and naturally accountable character of interaction, an achievement that requires a vulgar competence in the work of the setting studied *and* an disciplined eye toward the practical interactional details *and* a way of presenting these results in a way appreciated by the "staffs of order production" (ibid.). As Lynch (1997) points out, the policy is not – as it is often claimed to be – a way to put the researcher in a position above others, or providing an ethnomethodological ground zero, but as a reminder that "professionals (social scientists, administrative analysts, and social engineers) do not monopolize the development and use of rules, formulae, algorithms, maps, guidelines, rules of thumb, maxims, instructions, and the like" (p. 372). This attitude of rejecting the FA methods normally applied in social science is often seen as strange and it has frequently created confusion among researchers. Much of social sciences legacy is built on general methods for corroborating or refuting results. What is left if these methods are removed and in what ways are other researchers supposed to make claims about the validity of the results? These questions have often been posed to ethnomethodologists and one occasion that in an illuminating way highlights this confusion, and EM's seemingly strange answer to these matters, is the Purdue Symposium on Ethnomethodology (Hill & Crittenden, 1968), which was arranged to provide practicing ethnomethodologists and other scholars an opportunity to discuss a range of issues concerning ethnomethodology's relation to sociology. In the symposium non-ethnomethodologists repeatedly tried to find *general* methodological procedures they could use in order to validate ethnomethodological claims.

> McGinnis: What criteria would you accept as grounds for arguing that it is false? What criteria would you require from me to assess my assertion that your claim is false?
> Garfinkel: Why don't you just state your objection? (Hill & Crittenden, 1968, p. 34)

In a comment on this exchange, Lynch (1993) claims that "Garfinkel's rejoinder casts McGinnis's *academic* question into a 'vulgar' conversational frame" (p. 146). While the question presupposes that Garfinkel's observation[10] should be able to be tested according to some general criteria of falsification, Garfinkel's answer was pointing to the particular case and the potential problems with *that* observation (such as incongruities, absurdities, errors of worldliness or facticity, gaps, omissions, hiding out or faking). In this way Garfinkel's reply questions the rationality of method "not through an explicit argument, but in the way it is submerged into a 'vulgar' competency" (ibid.)[11]. Taking an EM position, there is no time out from ordinary mundane society, no privileged analytic vantage point or method that provide a guarantee of valid results.

It is common to interpret indifference as a claim that EM studies cannot pass judgment or be prescriptive. As have been discussed earlier in this section, approaching practices from the position of EM indifference means refraining from using exogenous theoretical categories when doing analysis and when making judgments. Such indifference does not, however, present any principled objection towards the subsequent *use* of descriptions in forming prescriptive judgments, only towards accounts that *explain* and *analyze* interactions in terms of such normative exogenous categories. Consider this original formulation of EM indifference from Garfinkel (1967):

> A leading policy is to refuse serious consideration to the prevailing proposal that efficiency, efficacy, effectiveness, intelligibility, consistency, planfulness, typicality, uniformity, reproducibility of activities—i.e., that rational properties of practical activities—be assessed, recognized, categorized, described by using a rule or a standard obtained *outside* actual settings within which such properties are recognized, used, produced, and talked about by settings' members. (p. 33, emphasis added)

The emphasis on *outside* is important, since it identifies as a study object the rules or standards for recognizing and talking about efficiency, intelligibility, consistency and the rest, that are used *inside* actual settings, by settings' members. Thus, normativity can be *part of* descriptions and thereby point to sensible suggestions of prescriptions. Given such an approach, issues of normativity are approached from the standpoint of the *setting* itself, and the interests and concerns of members. It should thus be possible, in principle, for a vulgarly competent ethnomethodologist to make judgments on *local pragmatic grounds* as to what could constitute an improvement on, for instance, an instructional innovation, provided that the sense of these categories does not derive from an a priori definition but rather from their presence as "professional designations" (Macbeth, 2002) in the setting itself.

FOCUS ON ACTION AND IMMANENT PEDAGOGIES, NOT LEARNING

In studies conducted by Charles Goodwin (e.g., 1994, 1995, 1996, 1997, 2000a, 2000b), the disciplined and accountable nature of competent seeing has been a recurrent topic. In these studies, Goodwin focuses on the actions through which practitioners highlight, make visible and learn to see aspects of their surroundings as relevant objects of their profession and, in relation to this, how professionals construct representations of these socially organized surroundings. Studying the visible and instructable character of competence like this could be seen as a way of describing the "immanent pedagogies by which members master their practices" (Lynch, 1993, p. 273). As we have mentioned earlier, our general interests is in the way that participants in an educational setting are made accountable for the disciplined competence that is purportedly being taught in that setting. In this way we hope to gain a sense of how a subject matter is made visible and instructable, especially with regards to the "interactional bringing to life" of "instructional innovations" (Koschmann *et al.*, 2004). Although Goodwin does not take any interest in instructional innovation or education, we believe they are exemplary examples of how immanent pedagogies can be investigated without resorting to theories of learning. To show what we mean, we provide a rather thorough account of one of Goodwin's analyses.

Goodwin (1994, 2000a) reports on a study where an archaeological field excavation of a prehistoric village was inspected and recorded. Maps of the excavation site are central to archaeological practice. In order to produce a map, relevant cultural features – such as the remains of a cooking fire and the outlines of the posts that held up a building – have to be marked out. Features are often visible as colour differences in the dirt and in order to produce a map these differences are systematically classified. In one analysed episode, a young archaeologist, Sue, is drawing a map under the guidance of Ann, a senior archaeologist. Seeing as an archaeologist, manifested here as being able to draw a correct map, is a central element of what it means to be an archaeologist. When collaborating in the production of a map, the two archaeologists have to see the scene in common, and see it in a way defined by archaeology as a profession. Since Sue is inexperienced, Ann must organize this professional seeing as a form of public practice by linking her actions to the dirt under scrutiny. In the concerted work of the two archaeologists, some of the embodied methods required to see and define the objects and distinctions central for subsequent description and analysis are made visible. In order to uphold a pragmatic intersubjectivity (Edwards, 1997) sufficient to get the job done, Ann is using different methods to show how the correct way to categorise the dirt is performed, which results in a "progressive expansion of Sue's understanding, as the distinctions she must make to carry out the task assigned to her are explicated and elaborated […] such that Sue is finally able to understand what Ann is asking her to do, that is understand in a manner that permits her to make an appropriate, competent response to Ann's request" (Goodwin, 1994).

Goodwin claims that situations such as the one described, where "multiple participants are trying to carry out courses of action in concert with each other through talk, while attending to both the larger activities that their current actions are embedded within, and relevant phenomena in their surround" (Goodwin, 2000a, p. 1492), could be seen as "the primordial site for the analysis of human language, cognition, and action" (ibid.). The reason for the "multiple participants" provision is mainly methodological. It makes available for the analysts, through the members instructions and corrections, how one conducts oneself knowledgeable in the face of a certain task. A related consideration lies in the specific choices of domains of study; the participant frameworks in the settings studied are often asymmetrically organized with respect to competence or "epistemic position" within the field. This provides for, again, the highlighting of the methods that go into the making of a competent practitioner; explicit sequences of repair and instruction of the novice's actions bring into view what constitutes right and wrong and so make visible the professional competence of the field[12]. We claim that these features of the sites and situations studied by Goodwin make them primordial sites for studying, not only language and cognition generally, but also instruction and competence. Through paying close attention to the details of how corrections and instructions are organized in a specific setting, one can gain a sense of how this setting *shows* the subject matter in structured ways. One can then construe the specificity of a setting in terms of how a lived work is done *as* the formal competence of that setting.

Goodwin seldom mention learning in his studies, although he do use normative descriptions such as "progressive expansion of understanding" and "appropriate, competent response". More importantly, he does not theorize learning. As Goodwin's studies make obvious, practical reasoning embedded in social interaction can be studied without ever treating it *as* learning. To be sure, people learn stuff, and if the analyst looks at what they do, he or she will see interaction and practical reasoning, and could in some particular cases also see that a person has learned something, but that does not imply that learning *is* interaction or practical reasoning. Learning already has an everyday grammar that involves, among other things, ascriptions of achievement and judgments about changing competences. But using it as a theoretical term designating something that people *do* constitutes a reworking of the grammar of the word that seems hard to motivate. We believe that analysis would benefit from being indifferent to any such arguments and simply say that learning is, to paraphrase Coulter (1999), "a polymorph of our language" and be content with that. This does not mean that a researcher, by investigating a particular course of interaction can say that a participant has learned something. We propose letting "learning" remain an after the fact characterization and that we refrain from thinking about learning as an object of *theoretical* reflection[13].

DO HYBRID STUDIES

The notion of hybrid disciplines envisages ethnomethodology as closely associated with the work-practices that it studies: "The intention of the hybrid programme is clear: it is to inform the ongoing professional development of occupational practices whose workaday objects are under 'praxiological' study" (Crabtree, 2004). Such a programme would dissolve ethnomethodology into a host of hybrid disciplines taking active part in the development of the studied practices. In the case of education, a hybrid science would be directed at studying educational practice with the intention of partaking in the development of that same practice. Now, the branch of educational research we have been discussing has just this interest: informing the ongoing professional development of occupational practices. Much of the problem with existing educational research, as we see it, is that it deals in theoretical abstractions and tends to miss the interactional "what" of educational practice; and we see ethnomethodology's contribution as providing the missing interactional what of instructional innovations, what they *are* as "brought to life" interactional achievements. We think that this could be an influential achievement with parallels to how ethnomethodological studies of technology has been received, or as Hester and Francis (2000), puts it:

> Indeed, if ethnomethodological studies of technology are taken as a precedent (Button, 1993), then professional educationists may find more of practical relevance in ethnomethodological studies of the detail of educational activities than can be found in other kinds of sociological work. Arguably, it is through such detailed inquiries that 'self-reflection' and hence improved practice may best be promoted. (p. 6-7)

In this field, the notion of hybrid disciplines has been developed in discussions concerning ethnomethodological input to technology design. One of the earliest initiatives in this area was made by Button and Dourish (1996), who proposed that design and EM was to forge a "foundational relationship", and then approach design from a new position (ibid., p. 22)[14]. Crabtree (2004) has sought to articulate what could be meant by such a foundational relationship. He sees ethnomethodology and design merging in a new organization of work that is iterative in structure, involving successive alterations of innovations worked up in concert by ethnomethodologists and designers. This hybrid lets the design process as a whole adopt the analytic mentality of ethnomethodology, at the same time as ethnomethodology "dons the practical mantle of design" (Button & Dourish, 1996, p. 22). An iterative way of working is also to be found in several accounts of *design-based research*. According to the Design-Based Research Collective (2003), good design-based research include five characteristics:

> First, the central goals of designing learning environments and developing theories or "prototheories" of learning are intertwined. Second, development and research take place through continuous cycles of design, enactment, analysis, and redesign […]. Third, research on designs must lead to sharable theories that help communicate relevant implications to practitioners and other educational designers […]. Fourth, research must account for how designs function in authentic settings. It must not only document success or failure but also focus on interactions that refine our understanding of the learning issues involved. Fifth, the development of such accounts relies on methods that can document and connect processes of enactment to outcomes of interest. (p. 5)

This is thus an approach to educational research that has tried to move beyond the purely descriptive explorative variety of qualitative research in education and approach questions of prescriptive judgments that has traditionally been reserved for quantitative or purely theoretical studies. Instead of comparing an innovation against a set of standards, a process of formative evaluation with iterative cycles of development, implementation and study allows the researcher to make an ongoing assessment of how the innovation is working. The outcome is seen as an interaction between context and innovation, a view that eschews randomized trials as the only or even an appropriate way of evaluating an innovation (ibid.). It is in such an iterative work that we see a place for ethnomethodology.

The analytic mentality of ethnomethodology, as we conceive of it, is described above in relation to the three first "imperatives"; it emphasizes *vulgar competence*, it is *indifferent to formal analytic theory*, and its adoption in actual studies reveals "seen but unnoticed" organizations of educational settings, through a focus on *immanent* *pedagogies*, rather than on theoretical terms such as learning. The contribution of such a mentality to an iterative design-work within education can be said to consist of a short-term influence on specific designs and a long term influence on the methodological and empirical foundations of educational design through, as Heath and Luff (2000, p. 240) phrase it, "taking practical action and human agency seriously".

As indicated above, vulgar competence enters as a prerequisite for conducting analyses of how learning environments show a subject matter and make instructable relevant competencies. Given the way such analyses reveal the standards of accountability that are used inside the setting – and the endogenous normativity involved therein – partaking in the making of prescriptive judgments should not be beyond the scope of the analyst's role. This is only true given that prescriptive judgments are based on local pragmatic considerations arising in the actual iterative design-work of which they are part. They are also to be assessed against such local considerations. The way we see the role of the ethnomethodologist in the design process is thus based on a way of thinking that attempts to steer clear of general characterizations, an "in each case" way of thinking, where the claims we make are to be seen as pointing to an imagined iterative design-process. The EM account does not figure here as a stand-alone isolable product, but rather forms part of an on-going practical work of continuously refining and analyzing the way an instructional innovation plays out in practice. In providing design evaluation and analysis with the analytic mentality of ethnomethodology, educational design can move beyond unproductive generalizations and untoward use of formal analytic theory.

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[1] Building on the work of Brown (1992) and Collins (1992), the notion of *designed-based research* or *design experiments* has the last few years been developed in special issues of *Educational Researcher* (Kelly, 2003), the *Journal of the Learning Sciences* (Barab & Krishner, 2001; Barab & Squire, 2004) and *Educational Psychologist* (Sandoval & Bell, 2004).

[2] When using this method, the researcher codes utterances based on a system of twelve different categories such as "shows solidarity", "gives an opinion" and "disagrees". Similar approaches of coding utterances are also common among educational researchers (e.g., 2001). By coding the interaction, events are made statistically analysable and surveyable. On the other hand, coding makes parts of the interaction invisible and the researcher might lose the practical details through which actions and activities are produced and recognized as those of a particular situation; thereby losing the possibility to "discover just what [an] innovation might be" (Koschmann *et al.*, 2004, p. 7).

[3] As Rawls (Garfinkel, 2002) maintain, the assumption "that orders is displayed in the concrete details of enacted practices is not only, or even firstly, a theoretical assumption, but also something one feels when observing empirically the patterned orderliness of certain social occasions" (p. 23).

[4] This formulation is taken from a manuscript that later was presented at the ICLS conference and our paper started off as a direct response to the paper by Koschmann *et al*. Since then, however, their paper has changed form and will be published in a forthcoming book on video research in the learning sciences (Koschmann *et al.*, in press) and as part of a chapter in a book on collaboration, learning and technology (Stahl, in press, chapter 18). When we wrote the first version of this paper, we had only access to the first version of their conference manuscript. Since we are more in agreement with later versions of the text, which might be due to a misreading of the original manuscript, we have reformulated or removed some of the explicit discussion of their text.

[5] See Plowman, Rogers, and Ramage (1994) for a critique of papers – within the field of CSCW – that "tend to offer a description of a case study, followed by an implications for system design section at the end of the paper in which a number of highly generalisable or semi-intuitive recommendations are made" (p. 4).

[6] Some research traditions, however, do not follow this scientific ideal. For instance, some *ethnographers* emphasize the importance of *going native* (Malinowski, 1922) while within *hermeneutics* and *phenomenology*, the centrality of the notion of sharing *interpretative horizons* of the societies, individuals or texts under study (Gadamer, 1975) points to similar issues. In a general sense, then, the claim that the researcher has to be competent in relation to the investigated phenomena is not specific to ethnomethodology. This is not the place to discuss all similarities and differences between EM and these traditions, though, especially since ethnography and hermeneutics could mean different things (and sometimes qualify as EM). For further discussion of the relation between ethnomethodology and phenomenology, see Heritage (1984, pp. 37-74) and Lynch, (1993, 117-158). Crabtree (2001) proposes a way of conducting ethnographies under the premises of ethnomethodology and Meehan (1999) discusses some differences between ethnomethodology and traditional ethnography.

[7] This formulation should not be taken as implying an adherence to a view of a stable and unique foundation of the discipline, a foundation that social science accounts could somehow *depict* or *be about*. The 'what' does not afford, or require, exhaustive description, but rather points to the mastery needed, in each case, for membership in the discipline. To emphasize this, Garfinkel's early use of the word 'whatness' (or quiddity) was subsequently dropped for its cognate 'just-thisness' (or haecceity), a term with a more obvious indexical character. As Garfinkel himself write: "When Willard Van Orman Quine published *Quiddities* it was clear that quiddities had nothing at all to do with what EM had uncovered. Most emphatically EM studies did not mean *essential detail.* EM is not interested in essential in any sense of generic provision for a properly formulated propertied class of thing. […] EM studies was not looking for *quiddities.* They were looking for haecceities - just-thisness; just here, just now, with just what is at hand, with just who is here, in just the time that just this local gang of us can make of just the time we need, and therein, in, about, as, and over the course of the *in vivo* work, achieving and exhibiting everything

that those great achievements of comparability, universality, transcendentality of results, indifference of methods to the local parties who are using them, for what they consisted of looked like, the 'missing what' of formal analytic studies of practical action." (Garfinkel, 2002, p. 99)

[8] The asterisk following the word "order" is used "as a marker to hold a place for any of the endless topics in intellectual history that speak of logic, purpose, reason, rational action, evidence, identity, proof, meaning, method, consciousness, and the rest. Any of the topics that order* is a proxy for should be read with an accompanying suffix: (order* - in-and-as-of-the-workings-of-ordinary-society. Then the topic of order* would be understood to speak of a *phenomenon* of order*, a practical achievement" (Garfinkel, 1991, p. 18).

[9] Garfinkel sometimes use the term *classic studies* or *classic methods* interchangeably with *formal analytic methods* and *constructive analysis*. All these terms, in somewhat different ways, point to alternates and alternatives to EM.

[10] From the case study Agnes, reported in (Garfinkel, 1967).

[11] In the same symposium, Sacks replies in a similar way when asked to tell "without reference to the subject matter" (p. 41) what an accepted EM "demonstration would be" (ibid.). He does this by reformulating the question: "Do you know what that us asking? You are asking, 'Could you tell me, without knowing what kind of world we are in, what a theory would look like?'" (ibid.), claiming that he does not "know in the first instance what it is that sociology should look like to be satisfactory" since "that is not an available phenomenon" (ibid.). See Lynch (1993, pp. 144-147) for a more throughout discussion of these exchanges.

[12] It makes visible the lived work that is *glossed* by abstract designations such as "mastery" or "competence".

[13] One way of theorise learning that has been criticized by ethnomethodologists is the common distinction between authentic and inauthentic settings (J. S. Brown *et al.*, 1989; Roth, 1995). Hemming et al. (2000), for instance, questions the comparison between the authentic everyday learning of language with the inauthentic classroom learning and claim that generalised descriptions of different pedagogies cannot capture the activities that constitute the settings. Instead they claim that the dichotomy between authentic and inauthentic settings "can be little more than rhetorical devices in service of a moral project" (ibid.) Similarly, Macbeth (1996) points out that there is a paradox inherent in the distinction since everything that are commonly ascribed to authentic practices such as "essential indexicality, intertwining, enculturation, and the rest" (p. 274) must also be found in classrooms "in and as the fundamentally situated character of sense and meaning." (ibid.). As Macbeth argues, since all practices are situated, the notion of situatedness does not offer a way distinguishing between different activities or an empirical or analytical ground for reforming education. He further maintain that the distinction neither works as an analytical criteria since sorting activities into the "right" category would probably only slow down the investigation and direct the attention away from the practical conduct of the participants. In the work of Hemming *et al.*, this line of critique is also directed towards Lave and Wenger's (1991) notion *legitimate peripheral participation*: "If learning can happen in 'ordinary settings', and occur in the course of activities not primarily or explicitly defined as 'educational', then what analytic constraints should govern the use of these descriptions? What is it about some activity which warrants the description of it as 'learning' and/ or 'teaching'? Notions such as Lave & Wenger's (Lave & Wenger, 1991) 'legitimate peripheral participation', however useful as the basis of a critique of cognitivist theories of learning, raise the serious methodological question of their own legitimate application. If learning is an unnoticed 'by-product' of other activities, activities whose primary participant recognised function is something other than the transmission of knowledge, then when (and on what grounds) is it correct and/ or incorrect to say that 'learning' is (possibly, relevantly) taking place?" (Hemming *et al.*, 2000, p. 229). Not only situative accounts of learning makes such transformations of analytical starting points, however, as Cobb et al. (1999) notice, in constructivism the "assumption that learning is a constructive process often leads to the slogan 'telling is bad' because it deprives a students of the opportunity to construct understandings for themselves." (p. 12) Taking a social constructivist position would from the same rationality imply that "students should continually discuss their differing interpretations" (ibid.).

[14] Button and Dourish list three different ways that the design-ethnomethodology relationship has been realized in CSCW research, phrased in terms of how design has "learned" from ethnomethodology. First, there is design "learning from the ethnomethodologist". The rich ethnographic understanding that the ethnomethodologist acquires in conducting her investigations of "user" practices allows her to function as a stand-in for the setting in which a design is to be incorporated. There is thus a division of labour, where the ethnomethodologist provides general ethnographic domain knowledge, and designers use this resource for formulating requirements for design. Ethnomethodology itself gains only a marginal role here, the ethnomethodologist's contribution being general domain knowledge. From the standpoint of design, she becomes substitutable for any fieldworker with detailed knowledge of the setting. Second, there is design "learning from the ethnomethodological account", where the division of labour is even more pronounced. In this organization of work, design does not learn directly from the ethnomethodologist, but from the accounts of practice that the ethnomethodological analyses result in. The locus of ethnomethodology as such is more central in this model, in that specifically ethnomethodological accounts are used, which requires of designers the ability to understand and use ethnomethodological analyses. The role of the ethnomethodologist however, is marginal. Third, there is the view of design and ethnomethodology forming a deeper connection, where design as a discipline "learns from ethnomethodology". This is the alternative preferred by Button and Dourish, and they propose that the design of technology should be informed by specifically ethnomethodological insights about the nature of social interaction, not just from the rich ethnographic knowledge gained by the ethnomethodologist or from specific accounts of practice. They illustrate their point with an example from their own work, where the notion of *accountability* was used to inform the design of user interfaces.

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How Representation Matters: Comparing Collaborative Learning with Alternative Versions of Hypermedia

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Abstract. The goal of this comparative case study is to investigate how students collaboratively learn about complex systems with hypermedia. This study also investigates how the conceptual representation underlying the hypermedia influences students' collaborative activities and knowledge co-construction. We use two different types of hypermedia to study the human respiratory system. One version of the hypermedia highlights the structural and the second version the functional-behavioral aspects of the human respiratory system. An in-depth analysis of two dyads, working on two versions of the hypermedia, will be presented in this paper.

Keywords: Knowledge co-construction, conceptual representation, hypermedia

INTRODUCTION

Concrete external representations can profoundly affect discourse (Suthers & Hundhausen, 2002) but there has not been any research that explores the role of *conceptual* representations on collaborative learning. Conceptual representations are often implicit in learning resources such as hypermedia and can be used to guide the learning process and alter the course of collaborative learning conversations (Suthers & Hundhausen, 2002). Prior research has shown that hypermedia can be an effective representational aid for individual understanding and problem solving (Jacobson & Archididou, 2000). The research reported in this paper addresses the question of how conceptual representations embodied in hypermedia have the potential to guide and support knowledge co-construction as we explore the effects on collaborative learning processes. In this paper, we present an analysis of two dyads working on two different versions of hypermedia.

THEORETICAL RATIONALE

Collaborative learning provides opportunities for learners to engage in constructive processing. Computer-based instructional systems, such as hypermedia, provide an opportunity for learners to develop shared conceptual understanding.

Research on peer collaboration suggests that students profit from peer interactions especially from communicative exchanges (Rogoff, 1990). Peer interactions may contribute to intentional conceptual change by arousing an awareness of the need for revision of knowledge, a very critical step towards conceptual change. The resultant disequilibrium might lead up to final conceptual change via integrating old and new knowledge.

The fact that computers can play an important role as representational aids for learning is well established (Kozma, 2000). Dynamic and visual computer-based instructional systems mediate learning through nonlinear and vivid representations (Hegarty, Narayanan & Freitas, 2002).

In addition to the diagrammatic representations, computers can also be used as conceptual representational tools that characterize expert understanding of a domain (Pea, 1993). We are particularly interested in how people understand complex systems and the conceptual representations that underlies expertise in complex systems domains. Complex causal systems can be represented in a number of different ways. We use structure-behavior-function (SBF) theory as the underlying conceptual representation to design hypermedia for instruction.

The SBF representation allows effective reasoning about the functional and causal roles played by structural elements in a system and helps in understanding how different levels of a complex causal system interact (Goel et al., 1996). Expert-novice comparisons in two complex system domains have demonstrated that novices tend to attend to structure and have little understanding of the functional and behavioral aspects of complex systems (Hmelo-Silver, 2004). Moreover, novices tend to understand salient aspects of a system. On the other hand, expert understanding is a coherent representation of structures, behaviors and functions. In current study, we propose that, to foster deep understanding, instruction needs to make function and behaviors salient.

We designed two versions of the hypermedia system: a function-centered and a structure-centered version. The function-centered hypermedia emphasizes the interrelationships within a system. This conceptualization is nonlinear and closer to experts' mental models. Like traditional textbooks, a structure-centered hypermedia should cause students to focus on structure and miss the connectedness within the system. A study comparing these two versions on individual learning has shown that students in the function-centered condition had better understanding of non-salient structures, functions, and behaviors of human respiratory system, such as cellular respiration, than students in the structure-centered condition. We followed up with a qualitative study to investigate how two dyads understand the human respiratory system with two different computer representations, namely the function-centered and structure-centered hypermedia.

METHOD

Participants

We enrolled 4 participants, grouped into 2 dyads from the educational psychology subject pool at a large public university. Each participant received course credits for participating in the study. All the participants were female.

Procedure

The first author ran the study with each dyad. The session was videotaped using two cameras. One of the video cameras was focused on the screen to capture what the dyad was viewing; the other one was focused on the two students. One dyad was randomly assigned to use the function-version of the hypermedia (F-dyad), the other to the structure-centered hypermedia (S-dyad). Each used their version of the hypermedia to learn about the human respiratory system. All the procedures were otherwise exactly the same for both dyads.

All participants were asked to take a pretest on the human respiratory system before starting to explore the hypermedia. After the pretest, the experimenter instructed the participants to explain to their partner what the content meant to them and how it related to what they already knew about the human respiratory system. Afterwards, the dyads were informed that they needed to explore the hypermedia system for approximately 40 minutes. After using the system, all participants completed a posttest on their conceptual understanding. All participants also completed a questionnaire on their attitude towards using the software and the collaborative learning activities.

Materials

The two different versions of hypermedia emphasized different conceptual representations. The function-centered version of hypermedia had the information organized around functions and behaviors of the components in the system. Learners using the function-centered version first viewed the two major functional-behavioral questions, which led them to explore the function of the whole system first, as shown on the left in Figure 1. Then they studied respective behaviors and structures. Alternatively, the structure-oriented version organized information around the structures of the system. Learners started with a diagram of the human respiratory system with links to each component in the system. Then they studied their behaviors and functions. Except for the different underlying conceptual representations that were used to organize the information, the two versions of hypermedia shared identical content. Figure 1 display the two different opening screens.

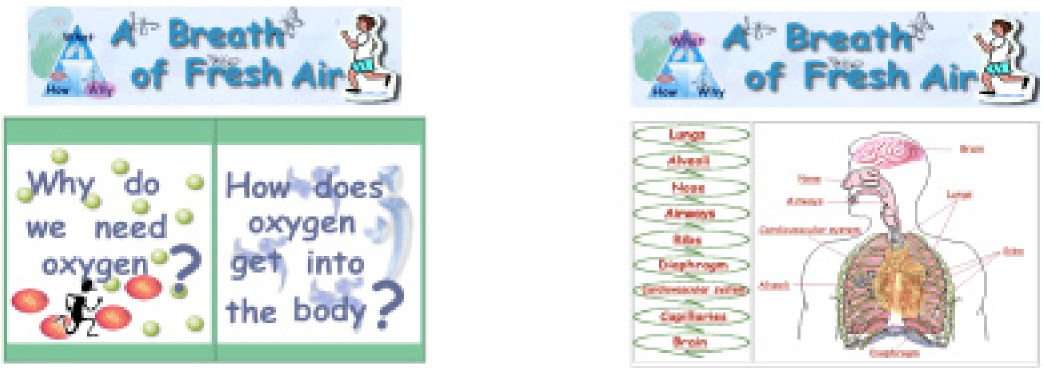

Figure 1. Opening screens of the function-oriented and the structure-oriented hypermedia.

Coding and Analysis

The tapes were transcribed verbatim blind to condition. The transcriptions were coded in three passes. The first pass was to divide the conversation into episodes marked by switches in the topic of a discussion. This was accomplished by reviewing the videotapes and identifying the screens that were being viewed. Screens on a specific topic, such as cellular respiration, lungs, transporting, were grouped as one episode.

In the second pass, each episode was coded into segments that consisted of five different discourse functions: social talk, task talk, reading, quizzing and negotiation. Social talk served to establish common ground or to allow the partners to become familiar, for example “Are you in Educational Psychology?” Task talk was about how learners would navigate the hypermedia, for example, "Should I click on this?" A reading episode involved verbatim reading of the text on the screens. Quizzing occurred as the students tested each other's learning. Finally, a negotiation episode was when the students attempted to share understanding and construct meaning.

In the final pass through transcripts, we focused on negotiation segments and identified discussions of prior knowledge, paraphrasing, elaboration/articulation, asking and answering questions (classified into structure, behavior and function questions), agreement, disagreement, metacognition, and talking about salient components vs. non-salient components of the system. All but the last categories are indicators of constructive processing and are associated with learning (Chi et al., 2001). The last category was coded because it was found in our previous research that novices regularly notice salient aspects and poorly understand nonsalient aspects, which are particularly important for a deep understanding of the system.

RESULTS

Both transcriptions were marked with conversational turns and words were counted. In the F-dyad's transcription, there were 250 turns and 2895 words in total. S-Dyad had 288 turns and 2333 words. Table 1 presents the segment number and percentage of each discourse function of both dyads.

Table 1. Distribution of discourse segments in both conditions.

Discourse Function	F-dyad	S-dyad
Social Talk	1 (1.3%)	5 (8.06%)
Task Talk	22 (28.57%)	26 (41.94%)
Reading	29 (37.66%)	18 (29.03%)
Quizzing	0 (0%)	1 (1.61%)
Negotiation	25 (32.47%)	12 (19.35%)
Total	77	62

Findings of an in-depth analysis of the dyads' collaborative discourses will be discussed in two main areas: sequence of episodes and knowledge negotiated.

Sequence of Episodes

During the first pass, we found some differences in the sequence of segments across the two conditions as shown in Figure 4. Another difference we observed is that, F-dyad engaged in more complicated sequences of the discourse functions compared to the S-dyad. For example, Figure 4 shows the sequences of segments on the topic of intercostals muscles in the two conditions. In particular, we focused on where the negotiation segments occurred in relation to other segments including social talk, task talk, and reading. We found that F-dyad engaged in the most negotiated episodes. In contrast, there was no such negotiation in S-dyad's discourse.

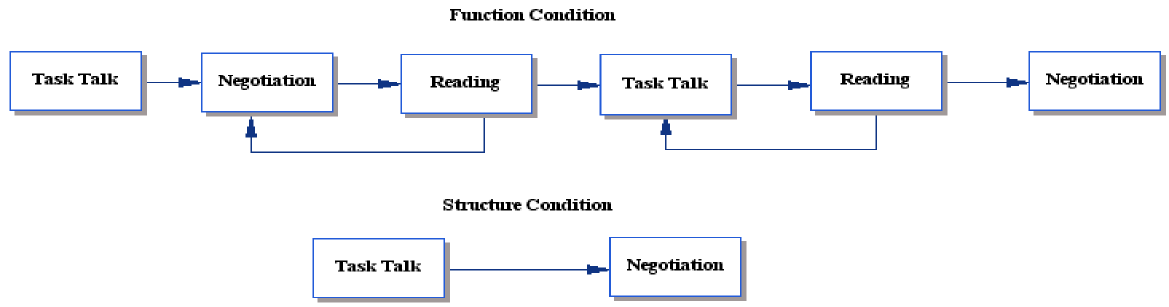

Figure 4. Sequences of segments on the topic of intercostal muscles.

Knowledge Negotiated

During the second and third passes through the data, we focused on what kind of knowledge had been negotiated among dyads and how this occurred. The following sections display our findings from three aspects: the kind of knowledge negotiated, types of questions that arose in negotiation, and the process of knowledge co-construction.

Nonsalient vs. Salient Knowledge

Consistent with our previous results (Hmelo-Silver, 2004), the F-dyad engaged in more discussion about non-salient phenomena. All the long negotiation segments occurred when the F-dyad discussed non-salient topics, such as cellular respiration, diffusion (functions of alveoli and capillaries), and how the vascular system works. But they did conduct a long negotiation when exploring the function of the diaphragm in the human respiratory system, a typical salient phenomenon. In addition, after completing navigation of the whole system with the function-behavior oriented hypermedia, F-dyad reviewed two topics on which they were still confused: the function of red blood cells and capillaries, both of which are non-salient but very essential phenomena in the human respiratory system. The following excerpt comes from this discussion:

Amy:	But we still haven't found out about the red blood cells?
Maggie:	Oh, yeah.
…	
Maggie:	Well, usually blood cells, just kind of, I know, they are in the blood, but maybe they are just help carrying…
Amy:	I thought blood cells, mm…, like protect our body from like…
Maggie:	I think, Oh, like immunization?… I think that's white blood cells. But I am not sure… cause my sister was sick a long time ago, and they are always monitoring her white blood cells… but maybe there is red blood cells too. I don't know.
Amy:	(searching the hypermedia) Oh… Maybe are any of those?
Maggie:	(pointing at the screen) So they go out? Oh, that's oxygen.
Amy:	Maybe red blood cells carry oxygen, but I am not sure.
Maggie:	It kind of looks like the oxygen was getting replaced by carbon dioxide in the red blood cells…
Amy:	Oh, yeah?
Maggie:	So maybe that's … Oh, wait … wait, why does it say carbon dioxide and oxygen?
Anne:	I don't really know. It feels like how carbon dioxide goes in there but it looks like it's going out there.
Maggie:	Oh, I bet because they are talking about capillaries and exchanging stuff.
Amy:	Oh, maybe that is when the whole, when the blood goes into the alveoli, whatever, and then it gives out oxygen, and then when it goes, what was that one part that we were having trouble with in the beginning?
Maggie:	With the capillaries?
Amy:	Yeah!

In contrast, the S-dyad's negotiations were very short. In addition, most of the negotiation episodes concerned salient topics. The following is a typical example of how the S-dyad engaged in negotiation when they discussed the red blood cells. Clearly, they are engaging in less elaboration and the behavior (diffusion) remains a black box.

Susan:	So there is lungs, alveoli or whatever, and they bring out …
Lisa:	They diffuse it …
Susan:	Into the blood, ok, diffuse it into the blood.

Behavior vs. Structure Questions

Another difference between two conditions lies in the questions that the dyads asked during the negotiation segments. Specifically, the F-dyad raised more questions and these were likely to be questions about system behaviors. F-dyad participants focused their discussions on "how" and "why" questions. In addition, their negotiations were mainly directed towards solving the problems they encountered when reading the hypermedia content. Driven by those questions and their knowledge limitations, the F-dyad spent most of their time in purposeful exploration of the hypermedia. For instance, in turn 50, Maggie asked "… do the capillaries take it (the blood) to the blood vessels or…?", and "How does it (the air) get there?" in turn 132. Amy also led several behavior-driven discussions. For example, in turn 86, Amy asked "what is it like, pushed out through the lungs first and then pushed out to the body, like … as it pumps or no?"

In contrast, the S-dyad asked fewer questions about structures. The few questions they proposed as well as the quizzing segments were mainly structure-oriented which was consistent with the conceptual organization of the hypermedia they explored. In comparison to the F-dyad, the exploration of the hypermedia by the S-dyad seemed to be aimless and lacked goals. It is also found that most of their navigational choice did not show a clear purpose. The S-dyad typically went to the main page first, and then selected the links to topics they had not yet viewed. In summary, the F-dyad seemed more motivated by the gaps in their understanding than the S-dyad.

Knowledge Co-constructed

In our third pass of coding, we analyzed what was been co-constructed by both dyads and how the knowledge was shared. The dyads took different approaches to co-construct knowledge or questions that would focus their efforts on sense-making. For instance, in turns 61-71, the F-dyad tried very hard to reach a shared understanding. At first, both Maggie and Amy expressed their confusion about the behaviors of capillaries. Before looking for the answer in the hypermedia, Maggie vaguely explained the behavior based on her own understanding. After searching for and reading the content on the page introducing the behavior of capillaries, Amy agreed with Maggie's previous explanation. Thus, Maggie and Amy reached shared knowledge through a combined processing of self-explanation (Chi et al., 1994) and searching for evidence to support an explanation. In addition, they also co-constructed the recognition of one unsolved question: what the relationship between capillaries and other components in the respiratory system is. Compared to the F-dyad, the S-dyad students realized that there was some confusion in their understanding, but they did not try to answer those questions. Since the S-dyad students did not persist in pursuing the questions, they showed little evidence of co-constructed knowledge during the collaborative interactions.

DISCUSSION AND CONCLUSIONS

Our results suggest that, like diagrammatic representations, conceptual representations affect how students co-construct knowledge. This comparative case study demonstrated that when students learned from a function-oriented hypermedia, they engaged in more constructive processing as well as discussing those aspects of the system that are typically difficult to understand—the nonsalient aspects. Although the function-oriented hypermedia seemed more difficult for the students to understand, it seemed to afford more opportunities for the students to recognize the limitations of their existing understanding and then, to jointly make sense of the system at the functional and behavioral level.

Since the content of the two versions of hypermedia is identical except for different conceptual organization of hypermedia, our results indicate that different conceptual representations affect how students learn collaboratively. Clearly, we are limited in the conclusions that we can draw based on data from two dyads. We are currently engaged in collecting and analyzing additional data to see if the collaboration patterns that we identified in this study are replicated.

Conceptual representations make a difference in how students engage in collaborative learning. Our in-depth discourse analysis suggests that the conceptual representation embodied in hypermedia affects collaborative knowledge construction. These results have implications for learning and instruction about complex systems. Too often, learning about complex systems means learning vocabulary, usually about structures (AAAS, n.d.). These results suggest that organizing learning around the functions and behaviors of the system engages learners in an effort after meaning. Moreover, our results suggest that different conceptual representations provide different affordances for constructive processing and collaborative conceptual change.

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A Structured Chat Framework for Distributed Educational Settings

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Abstract. Chat tools are an integral part of many collaborative e-learning environments. However, standard chat tools suffer from important coordination and coherence deficiencies. The solution proposed in this paper is a generic framework for building malleable structured chat applications. The paper discusses the approach and the main design decisions, emphasizing the importance of dynamic malleability in educational settings.

Keywords: chat, structured chat, computer-mediated communication, process-centric system, generic framework, malleability, on line education, cooperative learning

INTRODUCTION

Chat tools are an integral part of many collaborative e-learning environments. Chat tools can support non collocated instructors and students in several domains. First, they can help to overcome the lack of corridor or water cooler talk, with unplanned informal discussions. Second, instructors or fellow students can schedule a chat session on a certain day, for a more focused but still informal discussion about some project or exam. Third, chat tool can support formal and planned learning sessions with a teacher and a small set of students, for instance under the banner of some constructivist learning practice. Young people in their late teens and early twenties have a great familiarity with chat tools. Those who would have significant difficulty writing a few sentences in a traditional course setting are able to keep a sustained attention and level of energy during chat sessions. However, in all these contexts, standard chat tools suffer from important deficiencies. In the second section we discuss these problems and define our vision for solving them by improving chat technology for educational settings. The third section gives more details about the main design decisions resulting from that vision. The fourth section briefly describes our current prototype. Finally, we discuss and evaluate the approach.

CHAT TOOL DEFICIENCIES

Informal Interaction Support

Many research efforts rooted in the sociological study of conversation have identified important coordination and coherence issues in standard chat tools (Garcia, 1999), (O'Neil, 2003). The most important is the lack of control over turn positioning. Since turns can be sent simultaneously by a number of participants, there is no guarantee that a next-turn, for example a response to a question, will appear directly after the question. Instead other turns may appear between the question and the response, causing confusion over threads. The consequence is a preference for short turns so that the response might be closer to the question, if sent quickly. Standard chats are not places where carefully constructed messages can be sent. Lack of visibility of turns-in-progress, because chat systems only transmit turns when they are completed (ENTER key), and lack of visibility of listening-in progress, because participants do not receive moment-by-moment information about the reaction of those who are listening to them, are other examples of well known coordination issues.

A number of research prototypes aim at addressing these problems with non standard interfaces like threaded interfaces (Smith, 2000), 2D/3D graphical interfaces (Viegas, 1999), (Kurlander, 1996), streaming media interfaces (Vronay, 1999). Innovative interfaces can solve one specific problem but often raise new ones in other domains (Vronay, 1999), and the change is often too radical for many end users. Another approach extends traditional chat tools with additional awareness mechanisms, each responding to a specific need. Researchers have proposed many punctual iconic or textual cues such as the social proxy of Babble for representing graphically user activity (Bradner, 1999), turns-in-progress visualization through the textual 'someone is typing' indicator, or social presence through animated face icons representing facial expression, hand raising, etc. (Fadel, 2004). In our opinion, such awareness mechanisms should be selectively available within consistent interaction styles for avoiding an excessive level of cognitive load. For instance, in a round robin interaction, user activity, turns-in-progress, and hand raising cues are of little value. The last approach considers that most of the deficiencies are consequences of the unstructured nature of standard chat conversations. By constraining the turn talking, a fundamental aspect of all virtual learning communities (Reyes, 2004), and by dividing discussions into more focused sub discussions, most of coherence and coordination problems will be alleviated. We think that educational settings strongly require such structuring capabilities.

Formal Interaction Support

In structured chat tools the rules governing the interaction (its process in a broad sense) are mechanically enforced for improving coordination and coherence. Several field studies have demonstrated that structured chat tools can help to support different kinds of formal interactions (Farnham 2000), (Pfister, 2002). This approach embodies into technology "social scripting" (Farnham, 2000), which is commonplace in face to face group interaction such as explicit meeting agendas, more or less implicit scripts for conducting interviews, brainstorming, and most of formal collaborative learning activities. In some prototypes, the rules are hard-coded (Pimentel, 2004). The imposition of inflexible structures is often resisted by participants*,* when poorly designed or missing the situatedness of human work (Suchman, 1987). People need to feel in control of a system according to their roles. So it is important to provide different forms of malleability to end users. We will discuss in more details our vision of malleability in the next section. The prerequisite is to have soft-coded rules, instead of hard-coded rules, by means of some interaction modeling language. In our opinion, most of the recent chat prototypes which follow this orientation suffer from important deficiencies: lack of expressive power of the modeling language in Lead Line (Farnham 2000), in which a process is simply a linear sequence of regular chat sessions, excessive complexity of the general purpose modeling language (colored Petri nets) in ProChat (Whitehead, 2000), lack of generality of the approach in the Learning Protocols approach (Pfister, 2002).

Our aim is to provide an open source framework for building malleable structured chat applications for distributed educational settings. It is based, among other sources of inspiration, on the most valuable lessons learned from other research areas dealing with flexible process-centric systems, such as process-sensitive software engineering environments (Finkelstein, 1994), workflow management systems (Agostini, 1997), and process-enabled cooperative hypermedia systems (Wang, 2000). Our prototype is called ωChat. Its applet client can be integrated into every Web-based collaborative e-learning environment.

ωCHAT APPROACH

Malleability

Malleability encompasses four different aspects.

- *Model evolution*. A process model is composed of three variations: a template definition (set of types) expressed in a model specification language, one or several enactable instances with the contextual information which makes them possible to execute, and one or several enacting instances created from the enactable ones with their execution states. (Finkelstein, 1994) distinguishes three styles of evolution: delayed change, when the template is modified but only future instances will be impacted, busy change, when the template is modified and the change is immediately propagated to all existing instances, and local change, when a single instance is modified with no impact on the template definition. In ωChat we are interested in delayed and local change. Unlike long term business process, there is no need for simultaneous evolution of all existing instances of a given template, because they are basically independent of one another. Delayed and dynamic local changes should be easy to perform by end users.
- *Model emergence*. Sometimes, the template definition itself can only emerge opportunistically and dynamically during the interaction, which includes a kind of meta discussion about how to proceed (Wang, 2000). No cryptic notation should be necessary for defining and instantiating such a new template.
- *Punctual constraint relaxation.* Any user should be able to relax or sidestep any specific constraint (without model evolution) when exceptional circumstances arise, the system making other users aware of these punctual rule breakings.
- *Customizable information and guidance.* The user interface should reflect in a natural and customizable way the current set of constraints which applies to a specific user playing a given role, and non intrusively provides an adapted guidance.

A Two level architecture for malleability

A central idea of our approach is to distinguish between a macro level (or process level), and a micro level (or protocol level), with different malleability properties. At the macro level, the process model specifies a sequence of phase types. Each phase type is characterized by a name, an informal description, and an interaction protocol type: open-floor, moderated open-floor, circular floor passing, single contribution, unique contributor (all predefined), and application-specific protocols (defined at the micro level). A library of predefined process model templates is available for reuse at room definition time. These definitions are stored in a declarative form (XML files on the server side), making delayed change easy to perform. When an enactable phase instance is created from the template, the user gives a name (by default the type name with an instance number), who is participating (if the phase has restricted participation), the binding of users to protocol-specific roles (e.g., who is the moderator in a moderated phase), some informal instructions for end users, and a set of optional mechanisms for customizing all client interfaces (use of utterance type labels, use of explicit referencing through the sequence number of the referred utterance in the chat history, …). The four malleability aspects of the previous section are fully supported at this macro level through simple interactive manipulations : the process model can emerge (e.g., a standard chat room is transformed on the fly into a structured, model-driven, chat room), the model can evolve (e.g., a new phase type is created, changed, or suppressed), and all constraints can be relaxed by users playing the predefined Room Operator role (e.g., the sequencing rule is relaxed by jumping to any previous or subsequent phase type, the participation rule is relaxed by kicking off temporarily a participant, the circular floor passing rule is relaxed by skipping a user, and so on). It is worth noting that the evolution power is into the hands of all people playing the predefined Room Operator role (which can be transmitted), not necessarily into the hands of a single heavy-handed dictator.

The micro level specifies interaction protocol types. Such a definition may require complex rules specification that cannot be performed interactively by an average end user. At this level, dynamic malleability is not fully supported. New protocols are only specified off-line with a declarative XML-based protocol specification language. An interaction protocol is defined by a protocol name, a non empty set of protocol-specific role names, a non empty set of protocol-specific utterance type names, and a non empty set of transition rules: <utterance_type> <role_type_1> → [<utterance_type_list> | all] [next | next_ circular | any] <role_type_2>, where [a | b] denotes a choice, and the keyword ‘all’ replaces all the values of a given set. It means that, depending on the type of the previous utterance and the role of the contributor, the next possible speaker (or role) is known with the set of possible utterance types. The table below specifies with this language one example of application-specific type (Pfister, 2002).

Protocol	*Role types*	*Utterance types*	*Transition rules*
Explanation protocol (Pfister, 2002)	Tutor Learner	Question Explanation Comment	Question Learner → Explanation any Tutor
			Explanation Tutor → all next-circular Learner
			Explanation Learner → all next_circular Learner
			Comment Learner → all next_circular Learner

THE CURRENT PROTOTYPE

The default client for interacting within an unstructured room or an open-floor phase of a structured room looks like any standard chat. This is important for people who are happy with such a basic tool. This default client can be customized both globally, by specifying interaction features at phase instantiation, and individually, through the Options Menu. For instance, displaying an ‘Info Panel’ for unsolicited awareness messages (such as ‘mary joined the room’ - see Figure 2) and query results. The ‘Can you talk?’ (see Figure 1) and ‘Are you op (Room Operator)?’ visual indicators are examples of individual customizations.

During structured phases, clients reflect predefined and protocol-specific roles. For instance, users playing the Room Operator role have ‘Next’ and ‘Jump’ buttons for instantiating and starting the next phase or any other phase of the structured room. In a moderated open floor phase, the Moderator’s client is the only one where new messages are immediately displayed (with the [MODERATE] label - see Figure 2). A publish window allows the Moderator to choose either to accept (broadcast) new messages or to refuse them (triggering a refusal message in a private chat session with their authors). During a phase using an application specific protocol such as the Explanation protocol specified above, users can only choose between a list of protocol-permitted utterance types when they have the floor (see Figure 1). All messages have a type label (e.g. {Explanation} - see Figure 1). This kind of controlled discourse should probably be restricted to specific and short time phases for avoiding the straight jacket effect pointed out in coordinator tools in particular (Winograd, 1986).

The following scenario illustrates different aspects of dynamic malleability. Jack (a teacher) is a Room Operator during a disorderly open-floor phase. At some point, Jack decides to kick off Peter (a student) for one minute (message 12 in Figure 2). Besides the use of this punctual mechanism, Jack decides also to change the current open floor room into a moderated one (himself being the Moderator) for a better control of the contributions. All clients instantly reflect that change: message 13 was un-moderated while message 16 is now moderated by Jack. Finally, Jack decides to add a ‘Summarization Phase’ after the current phase with a circular floor passing protocol: this local model evolution is performed interactively (see Figure 2). Instantiation will be done later, when the ‘Summarization Phase’ instance will start (‘Next’ or ‘Jump’ buttons).

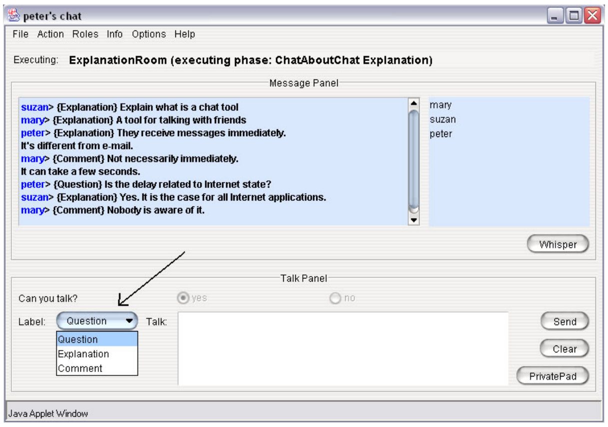

Figure 1. The Explanation protocol at work

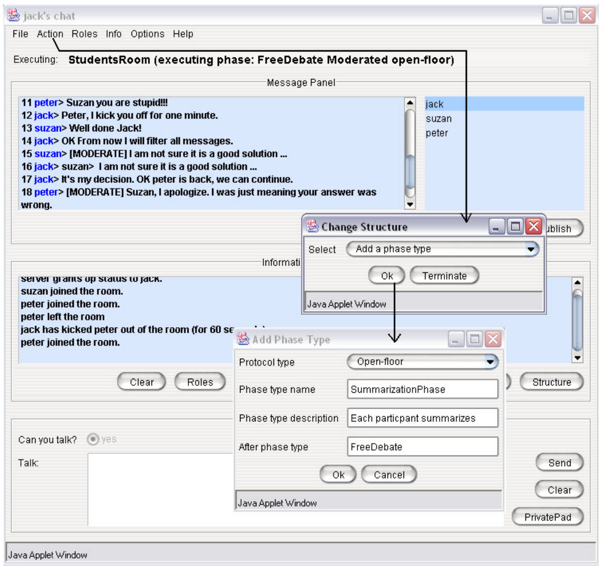

Figure 2. Examples of dynamic evolutions

DISCUSSION AND EVALUATION

From the collaborative work perspective, ωChat is a fully-fledged generic framework for building flexible chat applications. It combines the process view of Lead Line (Farnham, 2000) and the protocol view of ProChat (Whitehead, 2000) and Learning Protocols (Pfister, 2002). One can argue that ωChat does not “invent a new way of chatting” but only a practical way of building flexible, domain specific, chat-based collaborative tools. However, through its malleability properties, ωChat provides new ways of controlling chat sessions, which can deeply change the way of chatting: end users can strengthen (or relax) constraints when it becomes necessary during a chat session. This is very important in the educational context. Teachers can control many parameters, such as the content of the turns (in the moderated style), the flow of turns (with the predefined and application-specific protocols), who are the participants, their roles, the overall knowledge construction process (in structured sessions). Teachers can react easily to concrete problems such as lack of participation, flying fingers domination, control of disturbing persons, etc. For formal learning sessions, it is possible to support different collaborative knowledge construction theories, such as reciprocal teaching, guided peer questioning (Weinberger, 2003), or Socratic group discussion (Hoeksma, 2004). All these theories aim to facilitate collaborative learning by specifying activities in collaborative settings, sequencing these activities and assigning the activities to individual learners through roles definition. ωChat allows to implement them flexibly, alone, or in conjunction with other collaborative tools.

Evaluation of ωChat is a complex task. As a generic framework, we must prove that the tool can support a large scope of formal learning sessions, i.e. evaluate its process and protocol modeling languages. Work is on progress for finding in the literature various scripted learning approaches and for supporting them with ωChat. The prototype must also be evaluated from the ergonomic point of view. Internal tests have already suggested several improvements to the initial version (now included in the first public release): providing a multi line talk zone instead of a single line for avoiding the “one line/one thought” hypothesis and encouraging more carefully constructed contributions, providing a private zone distinct from the talk zone for preparing these contributions, making private sessions (whispering) a controlled optional mechanism, etc. ωChat adoption is promoted in two ways. First, we provide the tool freely, as on open source software (http://omegachat.sourceforge.net). Second, we are integrating ωChat into a workflow-enabled community platform for CSCL practice and dissemination. The example of open source software demonstrates that a large exposure to a community of practice is a very effective way for testing and improving innovative tools.

CONCLUSION

This paper describes our approach for defining a multi purpose chat technology for educational settings. For a long time, the value of chat tools for sharing insights and thoughts, for making decisions and reaching consensus, for quickly clarifying ambiguities and obtaining immediate replies has been acknowledged (Talamo, 2001).

ωChat is a generic framework for dynamic and fluid management of structured learning processes. It provides dedicated “interfaces” adapted to four categories of users having different requirements for evolution: passive chatters, who just communicate in accordance with the current interaction rules, active chatters, who are interested in maintaining the best organization for the ongoing interaction process, interaction designers, who prepare in advance, without programming, new application-specific ways of interacting, and tool developers, who customize the framework at the code level and integrate it within larger collaborative environments. We hope that ωChat could be more successful than previous attempts for imposing structure to synchronous text-based discussions because it allows to introduce innovative interaction modes progressively and reversibly during the collaborative sessions.

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We Learn Better Together: Enhancing eLearning with Emotional Characters

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Abstract. In this paper we explore a new direction for pedagogical computer characters, which we believe will maximize students' learning gains and enjoyment. To the traditional scenario where students interact primarily with a single coach or tutor character on-screen, we introduce the addition of both a social, animate colearner, and the student's own avatar character. Variations of the colearner's attributes, informed by research literature on human partners, are explored through an online testbed application of English language idioms. Results from an experimental study with 76 Japanese college students reveal that cooperative colearners have a positive impact on students' performance and experience, as well as increasing perceptions of the character's intelligence and credibility. Findings provide grounding for a fruitful new direction for pedagogical characters, where students learn alongside emotional companions.

Keywords: Pedagogical computer characters, evaluation of computer characters, language learning, colearners.

INTRODUCTION

Artificial intelligence applications in education most often appear as tutoring systems, diagnosing students' misconceptions on subjects such as algebra through problem solving activities and prearranged prediction patterns. Recently a new breed of agents has begun to surface in everyday applications: these agents appear on screen as embodied entities – whether humans, or anthropomorphized objects and animals – facilitating our interactions with software applications, navigating menus and web-pages, offering tips and customizing our online purchases. These embodied agents converse and interact with humans through text bubbles, sometimes accompanied by sound clips of their utterances, often expressing colorful personalities through animated gestures.

Drawing inspiration from traditional cartoon animation and comic layout processes, these characters resemble actors in their emotional range and improvisational responses. From the Microsoft helper agent, to company spokesperson, to customer service representatives on Dell.com and buy.com, computer characters are rapidly gaining prevalence in our everyday online activities, and with good reason. Computer characters have been shown to be effective proxy sellers, customer service representatives, and teachers, by engaging our unconscious social nature through life-like language, presence and behaviors (Reeves and Nass, 1996; Thomas and Johnston, 1981; Reeves, 2001). Of particular importance for the educational domain, characters, when properly deployed, may generate additional interest and motivation in the content presented (Moreno et al, 2000), and influence a proactive change in everyday behavior (Bickmore et al, 2004).

Pedagogical characters have appeared in language learning applications (Hayes-Roth et al, 2002), middle school curricula (Lester et al, 1997; Moreno et al, 2000; Biswas et al., 2004), oral storytelling (Kehoe et al, 2004), corporate training (Extempo, 2004), health behavior change interventions (Bickmore et al, 2004), and even military instruction (Johnson et al, 2004).

Previous research and industry applications on embodied conversational computer characters in pedagogical domains has conceptualized the interaction between the human and the computer character as a one-to-one tutoring or coaching intervention. The learner primarily interacts with one character on the screen at a time; when more than one character is present simultaneously in the application, their roles tend to be supplementary or supportive ones, providing background tips for the interaction as an articulate "Help" menu option or enriching the background of the activity as non-interactive extras, often called non-player characters.

We believe that giving the student a virtual presence in the environment, and enriching the learner's world with a colearner will lead to greater gains in learning and enjoyment of the educational application. To that end, we have designed and built an online application testbed, where we vary characteristics of the colearner to evaluate research-based predictions of factors that maximize achievement and enjoyment. We report on the first experimental study using this eSchool application, focused on teaching Japanese college students American idioms. The results offer great promise for breaking free of the traditional paradigm of a single interactive character on the screen, while revealing further research questions for pedagogical characters .

In the archetypical pedagogical character application, a computer character on the screen presents material, situations and questions, through images, videos, text and voice. The character may be embodied, or represented on screen as photographic images and videos, photorealistic 3d images, and even 2d anthropomorphized animal characters. To respond, human learners type comments, or choose from options presented by menus or buttons. Feedback on the learner's performance is then delivered through the characters, such as an explicit rating or goal achievement scale, or through the environment itself. For example, in certain simulations, the learner's behavior impacts the scenario illustrating, through the on-screen characters' behaviors, potential consequences and nuances of interpretation, enriching traditional numerical ratings with affective performances. This feedback can be both formative, as the learner progresses through the interaction, and often summative at the completion of the curriculum.

Computer characters exhibiting realistic behaviors in the pedagogical arena tend to follow three primary models, mirroring Taylor's 1980 taxonomy of computer usage in schools: tutor, tool and tutee. Characters may be cast as expert teachers or coaches, presented as role-play partners in simulations of real-world situations, or act as learners whom the human student teaches. Most often, computer character inhabit the role of expert or knowledgeable teacher (Hayes-Roth et al, 2002b; Baylor et al, 2004; Lester et al, 1997; Moreno et al, 2000). While these characters may be embodied as older or of a similar age to the human student, they interact with the students as experienced coaches and erudite tutors.

The second category, where characters are presented as partners in role-play simulations is prevalent for on-the-job training and eLearning situations, where the learner may be older and more experienced. In these cases, rather than an expert teacher, computer characters act as colleagues and coworkers. These characters foster learning through realistic role-play scenarios as the human student practices concepts, strategies, and behaviors (Extempo, 2004; Johnson et al., 2004; Aldrich's Simulearn company). A third mode of interaction with computer characters prevalent today presents the computer character as a learner, progressing alongside the human student (Maldonado et al, 2004), or being taught by him or her (Biswas et al, 2004). Peer characters, unlike the expert coach and tutors, are perceived as possessing as much content knowledge on the subject as the human learner, and often less. In cases where students teach the peer character, the cyclical act of preparing content for teaching, and successfully communicating it becomes the learning experience in itself.

LEARNING WITH CLASSMATES

In the last twenty years since Taylor published his taxonomy, we have developed the technologies to implement and render believable, animate characters, yet we have made comparatively little progress in developing applications for these characters that maximize the social and emotional relationship with human interactors. For each of the three modalities described above the human student tends to be implicitly present alongside the character, rather than visually embodied on screen, and the interaction is limited to exchanges between the human learner and a single computer character. Graphical representations of the human users that appear on-screen, are often referred to as avatars, which can be directed in their interactions with other computer characters in the environment, whether autonomous or directed avatars themselves. Despite few occasional appearances in educational applications (Maldonado 1998a, 1998b; Johnston et al, 2004), avatars frequently appear on many commercial sociable applications (Clanton et al, 2003; DiPaola, 1999; Wright, 2003), with varying degrees of autonomy: users may direct the avatar to perform specific behaviors and utterances or, at a higher level, indicate a preference or direction and let the avatar fill in with appropriately corresponding behaviors, gestures, onomatopoeias and comments.

We propose a radical reframing of the learning context in which students interact with animated pedagogical computer characters, which we believe will maximize the students' learning gains and enjoyment. In the eSchool application we have developed, students interact with *two* computer characters at the same time, a teacher and a peer fellow student, within one screen. Students are themselves represented through an avatar, whom they can direct in emotional and subject matter responses. The avatar's conversational behaviors and gestures are autonomously derived from the directions given by the human learner and the learner's answers to the teacher's questions. Research suggests this combination of high-level directions and autonomous behavior is perceived as more natural than avatars whose behaviors are minutely controlled by the users, leading to increases in perceived expressiveness of the conversation, and greater sense of user control (Cassell et al, 1999).

Figure 1 shows the eSchool interface for handheld computers from 2003 using cartoon characters, and Figure 2, the current interface on a PC using photographic images at the exact same moment in the interaction. In both cases the teacher character is located on the upper right hand side of the screen, above the chalkboard, which, in turn, displays the multiple choice interpretations the student must decide between, mimicking the learning space of a classroom. In Figure 1, the students' avatar is Neko the cat, and the colearner is Taro the Tiger, while in Figure 2 the students' avatar is Susy and the colearner is Ryota.

Each of the three interactors has their own emotions and embodiment, built for adaptation across platforms and conditions of analysis. The eSchool environment is written in Java, allowing students to conduct all their interactions online, perhaps across different days and computers as they progress through the lessons; the system will record the state for every student that logs in through a database driven registration process.

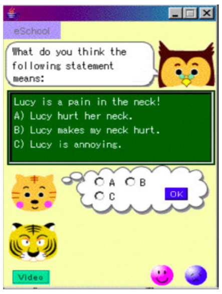


Figure 1: eSchool 2003 for Handhelds featuring cartoon characters

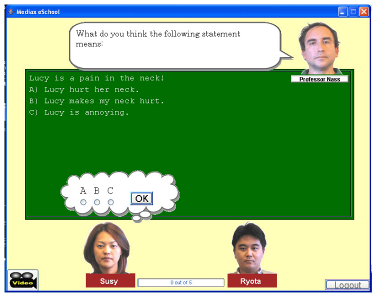


Figure 2: eSchool 2004 for the PC featuring photorealistic characters

Figures 1 and 2 show only some of the possibilities available within eSchool: students can choose the look and feel of their avatar and their colearner from a wide range of embodiment options: nine different anthropomorphized animals in 2003 and ten photorealistic humans in 2004, five male and five female. The actions the avatar and colearner take affect each other's emotions accordingly, and this change is reflected in their facial expressions, following the model of Ekman's (1992) universal or basic emotions: anger, sadness, disgust, surprise, fear, and enjoyment or happiness. Answering a question right, for example, increases the student's confidence and happiness, and also affects the emotions of the autonomous peer colearner, depending on his or her personality traits. The emotion model is grounded on personality traits, and the underlying architecture that modulates the emotions of all three characters is a novel, patent-pending design, product of a unique collaboration between Omron Corporation and Stanford University (for more implementation details, please see Morishima et al, 2004; Nakajima et al, 2004), and allows for a synchronous learning experience as well. That is, two students can interact through their avatars online in eSchool, although for the purposes of our experiments we have isolated the behaviors under analysis by modifying specific attributes of the colearner as an autonomous character. Unlike human confederates sometimes used in experimental studies, characters can reliably showcase the same pattern of behavior, with slight improvisations, for every user.

The colearner, or classmate, as its name indicates, is learning alongside the human student and has no additional knowledge on the subject nor explanations to provide. It is not privy to additional information than the student views on the screen, and is called to answer questions as often as the student, on average. The colearner exchanges friendly banter with the student's avatar before the teacher poses a question, or after the answer is revealed. We have introduced this presence in the learning environment to determine the effects that learning alongside a social animate character has upon the student's performance and attitudes, rather than using the colearner to elicit nuanced explanations from the student, or model understanding, as is the case with some intelligent tutoring systems (such as Goodman, et al., 1998).

The focus of our eSchool project on the coleaner is an innovative aspect of our character-based system, a research direction we believe fruitful to explore for computer supported educational interventions in a wide range of contexts, from eLearning seminars, distance education programs, to after school activities, in-class complementary modules, and behavioral change interventions. Thus far, experimental research has focused primarily on the modality of the exchanges between the teacher character and the human student, as well as the character's believability: text vs. voice (Moreno et al, 2000), photo-realistic vs. drawn representations (Baylor, 2004); two vs. three dimensional presence (Shinozawa et al, 2003); human-like vs. anthropomorphic animals (Moreno et al, 2000). Some studies have varied the degree of animated behaviors (Lester et al, 1997; Moreno et al, 2000), and others have explored ethnic and gender combinations between the learner and the character tutor (Nass et al, 2003; Baylor, 2004). In contrast, we are conducting several experiments evaluating the effects that different dimensions of the colearner have on the students' performance. Among the colearner dimensions we are studying are social ones (competitiveness and cooperativeness), personality traits (degrees of introversion and extroversion), and performance (high- to low-achiever). We are seeking out instances where colearners influence students' learning outcomes and attitudes through their behaviors, with the aim of gradually expanding the focus to study how these behavioral expressions relate to the students background, performance, personality profile and preferences.

PILOT APPLICATION

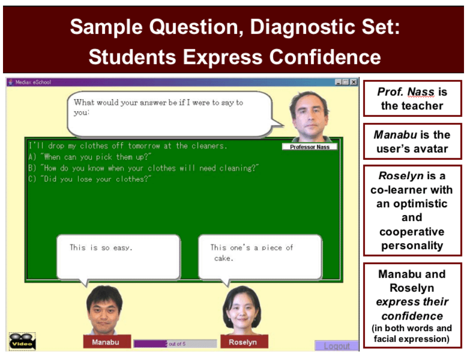
We inaugurated the colearner research field by isolating the effects of the autonomous colearner in an experimental study with three conditions: in the first of these, the colearner was not present, and the student interacted directly with the teacher character. We call this control condition the "No Colearner Present" condition. In the second condition, the colearner was present but did not interact with the student. While it answered questions when called on, in this "No Emotion Colearner" condition, the colearner character did not exchange or respond to any social banter with the student avatar in neither words nor gestures. Researchers such as Zajonc (1965) have noted that the presence of an audience tends to enhance performance and inhibit learning, although even he points out that some studies suggest an increase in learning scores in the presence of other people who learn with the individual. With the “No Emotion Colearner” condition we sought to study how the mere social presence of the colearner, even when it did not interact directly with the student, would affect the learning experience.

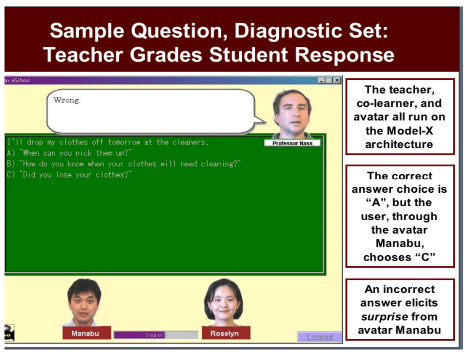
Research suggests that studying in a cooperative group leads to greater learning gains than individual or competitive conditions, with improvements in critical thinking skills (Stockdale and Williams, 2004; Skon et al, 1981), and to greater gains in motivation (Bickmore, 2005; Wentzel, 1997). Accordingly, our third condition featured a cooperative colearner. While most previous research attributes the performance gains of students in a cooperative group to shared reasoning and dialogue, we are interested in exploring the effects that colearners’ social banter may have on the student’s performance, even when it is devoid of educational content relevant to the learning activity at hand. Therefore, our third condition is the “Cooperative Colearner” condition, where the colearner’s social nature was manifested through utterances directed at the student’s avatar, making compliments and showing concern, particularly as the difficulty level of the questions increased or when the student missed a question. For example, when the student through his or her avatar answers a question correctly, the collaborative colearner may utter one of ten supportive utterances, such as “I knew you’d get it right!” or “That was hard, and you got it!” If the student’s avatar had answered incorrectly, the collaborative colearner may say: “This is very tough,” “I didn’t know that one either,” “You’ll get the next one!,” “I would have given the same answer, this is hard,” among other possibilities.

In addition to supportive utterances, in the “Cooperative Colearner” condition, the colearner also expresses support through appropriate changes in its facial expression. By creating a sense of unity between the self and the other, cooperativeness promotes friendship and perception of social support, which in turn may contribute to enhancing social relationship and performance both in dyadic and group interaction (Argyle, 1989; Argyle 1991; Deutsch, 1949). Because we sought to isolate the effects of the colearner character’s emotive, the teacher character in this evaluation did not exhibit any emotions, in his speech or expression.

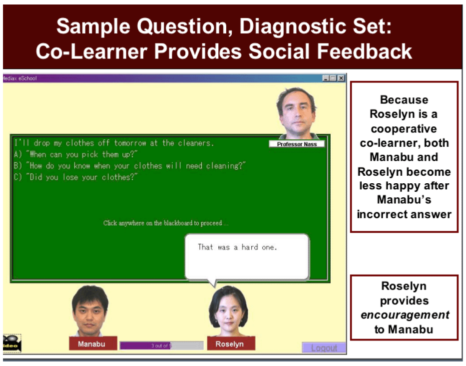
For the current eSchool web-based implementation, we have developed an intermediate English language lesson, accompanying video, and evaluation instruments, primarily aimed at Japanese college students enrolled in English language courses at Japanese universities. Students progress through fifteen multiple-choice questions about American idioms, a topic whose relevance to the target population was predetermined through a focus group study. Our target population has already mastered grammatical and syntactical nuances of the language and is interested in improving their understanding of colloquialisms commonly used by their American counterparts. As Figure 1 highlights, the interface design of emotive cartoon characters for eSchool 2003, was explicitly developed in Japan to be appropriate for the target audience, in terms of aesthetics, experience, culture and age. As we shift our focus globally with the online release of eSchool 2004, available to students anywhere, we have redesigned the interface for appeal to a broader audience, with photorealistic characters, and an emphasis on emotional expressions based on globally recognizable features (Ekman, 1992).

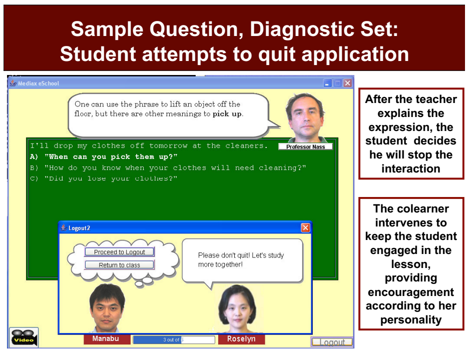
The idioms covered in eSchool lesson plan currently include: “being a pain in the neck,” “to drop off an item,” “to drop in,” “to drop out,” “getting cold feet,” “getting up the nerve,” “being tongue tied,” “being chicken,” “being a scaredy cat,” “being a couch potato,” “pulling someone’s leg,” “hitting the books,” and “hitting the town.” These idioms are organized in three groups of five questions each, according to their difficulty and grammatical similarity. Progress through the diagnostic, basic, or advanced question sets, is represented graphically on the screen through a progress bar between the images of the avatar and colearner, as can be seen in Figure 3.





Figures 3a and b: Typical question-answer interaction in eSchool 2004, featuring a cooperative colearner. Highlights the avatar’s emotional reactions to the questions posed by the teacher.





Figures 3c and d: Typical question-answer interaction in eSchool 2004, featuring a cooperative colearner. Showcases the cooperative comments and expressions of the colearner.

After the initial diagnostic questions, a video featuring an American college student discussing graduation with a Professor is played, using several typical idiomatic expressions. Students are able to see the video as many times as they wish, in its entirety or by choosing segments to review, and we record the viewing pattern for post-experience comparisons. Ten questions of increasing difficulty follow, based on the expressions covered in the video. The student's answers to each question are stored in the eSchool database for comparison as well, and affect both the confidence and emotional state of the characters. For example, in Figure 3a we see both the avatar and the colearner autonomously making statements of confidence, after the teacher has posed a question, based on their internal emotion model.

The teacher character then calls on the student or the colearner to reveal their answer on screen, determines its appropriateness for the question, and explains the origin or usage of the expression. On average, the teacher will call on the learner for 60 percent of the questions, while the remaining 40 percent will be answered by the colearner, which has been programmed to have a 50 percent chance of guessing the correct response each time s/he is asked to reveal the answer. Independently of the correctness of the answer revealed, the same teacher explanation will be seen by every student and colearner, to ensure that every participant is exposed to each aspect of the lesson content. For example, in the previous question scenario, the teacher explanation is as follows: "To drop something off is to leave something in a place for others to pick up. One can use the phrase to lift an object off the floor, but there are other meanings to *pick up*. One can use it to mean collecting an object from a place where it has been left, or where it is being fixed."

In the previous example, avatar Manabu reveals his choice when called to present an answer. Given the high level of confidence we can observe in Figure 3a, when the student's respond choice is incorrect, avatar Manabu expresses surprise, as we can see in Figure 3b; this emotional expression is appropriately and autonomously produced by the emotion engine, rather than a direct input from the student. Immediately following Manabu's surprise, the colearner makes a socially appropriate cooperative comment, captured in Figure 3c ("That was a hard one"). When the discouraged student tries to quit the application, the colearner intervenes to entice the student to continue the lesson, in a socially appropriate manner. In Figure 3d we can see the choices on avatar Manabu's bubble ("Proceed to logout" and "Return to class") and colearner Roselyn's plea to continue: "Please don't quit! Let's continue studying together!"

EVALUATION AND RESULTS

For our first evaluation of the eSchool system and underlying emotion-generation architecture, we partnered with an English language college class at International Christian University, in Tokyo, Japan, and sought to determine the impact of the colearner character on the students' understanding, recall, recognition, and motivation. Seventy-eight students were randomly assigned to one of three conditions; of those that chose to respond, 25 were male and 51 were female. Of these 76 respondents, 25 students interacted with the "Cooperative Colearner," a different group of 25 interacted with the "No Emotion Colearner," and a third group of 26 students interacted with the eSchool system in the "No Colearner Present" condition. Students interacted with the eSchool system at their school's computer lab, and then answered an online questionnaire. The entire process of interaction within the eSchool environment and questionnaire response lasted approximately an hour. The questionnaire covered attitudinal responses to the software system, probed their perceptions of the colearner character, if there was one present, and included a learning assessment metric with open-ended questions. These latter questions are of particular interest for our evaluation, as we sought to differentiate a gain in understanding and learning from rote memorization, recognition, and chance guesses, that plague typical recall multiple-choice assessment instruments. Students were asked to fill in the blanks in 11 sentences using some of the colloquial idioms covered in their interaction, completing grammatically correct sentences similar in meaning and structure to those presented through the lessons. For example, one of the fill-in-the-blank questions was "How could you believe what he said? He was just ________________." (The correct answer would be "pulling your leg".)

Before analyzing the results, two preliminary checks were conducted to certify the study results. Given concerns on the differential number of participants' by gender, a contingency-table Chi-square test was conducted to determine that the gender did not have particular effects on the intervention results. The observed Chi-square value indicated that the participants' gender was balanced across conditions (χ^2 (2) = 1.59, ns.) Because of the importance placed on the learner's feelings of being supported and cared for in the literature and in our research-based design, we included items on the questionnaire to validate our belief that our cooperative colearner was perceived as such. The participant's ratings of the colearner characters as "cooperative," "warm," and "caring" on a 10-point scale were compared based on an additive index of the three items. Because the control condition did not feature a colearner character, it was excluded from this comparison.

For this manipulation check, the participants in "Cooperative Colearner" condition (M= 6.04, SD= 2.84) rated their colearner as more cooperative than those who were in "No Emotion Colearner" condition (M= 3.12, SD= 1.88), and the mean difference was statistically significant (with equal variances not assumed according to the Levene test for equality of variances) t (43.46) = 4.38, $p < 0.001$. Second, with respect to the rating of the colearner character being "warm", the mean score of those who participated in the idiom lesson in "Cooperative Colearner" condition (M= 6.62, SD= 2.48) was significantly higher than the participants in "No Emotion Colearner" condition (M= 4.80, SD= 2.31), with equal variances assumed, t (49) = 2.70, $p < 0.01$. In addition, the participants in "Cooperative Colearner" condition gave a significantly rating of the colearner character as "caring" (M= 5.31, SD= 2.21) than those who were in "No Emotion Colearner" condition (M= 3.38, SD= 1.86), t (50) = 3.40, $p < 0.01$. From this analysis, we conclude that participants accurately perceived the substantial differences in the treatment variable, and interpreted the emotive colearner to be "cooperative," "warm," and "caring," as designed in the "Cooperative Colearner" condition.

Yet as characters in books, theater and television demonstrate, viewers can attribute cooperation and friendliness to performers without perceiving these attributed feelings as directed to themselves, the audience. Therefore, we set out to ascertain that the students felt supported by the colearner throughout the interaction. Since studying in a cooperative group leads to greater learning gains than individual or competitive conditions, with improvements in critical thinking skills (Stockdale and Williams, 2004; Skon et al, 1981), we were interested in whether our cooperative colearner was perceived as cooperative *with* the participants when compared with the unemotional colearner.

As feelings of support, and of being cared for have profound effects in cognition, emotion and even physiology, effects that are particularly relevant in educational settings where motivation is key (Bickmore, 2005; Wentzel, 1997), an index of "feelings of being supported" was created based on three items ("Not Alone," "Praised," and "Supported"). The participant rated how well the given adjectives described their feelings during their interaction with the colearner on a 10-point Likert scale: constructed to indicate that the higher the score, the more emotional support experienced. A factor analysis showed that the three items were loaded on a single factor, and the reliability test also indicated that the index could be reliably used (Cronbach α = 0.74). Hence, the "Cooperative Colearner" condition (M= 6.04, SD= 1.75) and the "No Emotion Colearner" condition (M= 3.90, SD= 1.07) were contrasted based on an independent sample t-test. The result (equal variance assumed according to the Levene test) revealed that the participants in "Cooperative Colearner" condition gave significantly higher ratings in feelings of being supported, t (50) = 4.47, $p < 0.001$, as can be seen in Figure 5. This result confirmed our prediction that the participants in "Cooperative Colearner" condition would experience the feelings of being supported to a greater degree than those who participated in the idiom lesson with a colearner character that neither uttered nor showed emotional expressions. Moreover, feeling supported and interacting with a cooperative colearner also impacted significantly students' learning during the intervention.

For the learning assessment, we concentrate on the eleven open-ended questions posed, as they signal a deep dominion of the idiomatic expressions presented interactively through the eSchool lessons. A preliminary analysis of the fill-in-the-blank responses led us to drop two questions due to misleading or confusing cues, as more than 80 percent of the respondents used content outside the lesson to answer. Therefore, only the responses to the remaining nine open ended questions were used in this analysis. Students typed into the text-boxes provided expressions that they believed would make the partial sentences presented sensible and grammatically correct, which resulted in wide variations of answer format. Each answer to the open-ended questions was assessed on a five-point scale, which ranged from "0" (left blank or irrelevant) to "4" (perfect answer), so that the maximum score possible in this section of the questionnaire was 36 points. Participants received partial points depending on the number of grammatical or spelling mistakes made per answer; two coders worked independently on the data set to ensure reliability. As few participants received scores above 25 points or below 12, we considered this assessment measure to be of adequate difficulty for our sample population.

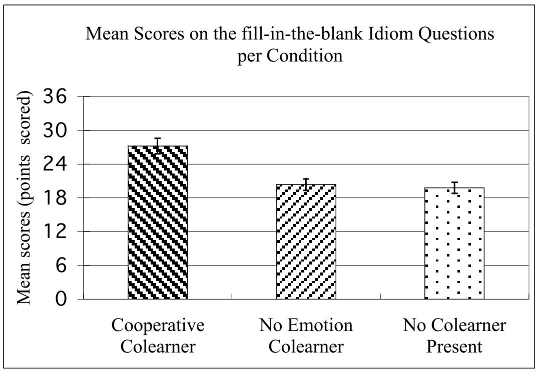


Figure 4: Participants' mean scores on the fill-in-the-blank questions.

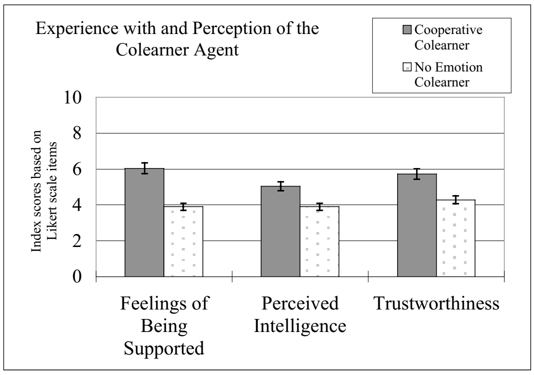


Figure 5: t-test comparisons between "Cooperative Colearner" and "No Emotion Colearner"

When participants' scores on these nine items were compared across the three conditions, the One-way ANOVA test indicated that the means differ significantly, F (2, 63) = 4.80, p < .05, η^2 = .13. In order to examine the differences more specifically, a post-hoc comparison was conducted using Scheffé test, one of the most conservative post-hoc comparison techniques. The result showed that the participants in "Cooperative Colearner" condition (M= 27.21, SD= 8.03) performed significantly better on the fill-in-the-blank questions compared to those who were in "No Emotion Colearner" condition (M= 20.35, SD= 9.97) and in the control "No Colearner Present" condition (M= 19.79, SD= 7.26), as can be seen in Figure 4.

For learning at least, it would seem that the mere appearance of an additional face does not trigger the same level of motivation unless it expresses emotions. And interacting with an unemotional colearner also diminished enjoyment of the system: in the attitudinal questionnaire participants filled out, six 10-point Likert scale items probed their feelings about the eSchool environment. Students were asked to quantify their agreement with statements such as "I would recommend this software system to other people," and "I would use this software again." The analysis of covariance of these items covering participant's impression of the system showed that the participants felt it was significantly less enjoyable to work with the system in the "No Emotion Colearner" condition, compared both to the "Cooperative Colearner" condition and the "No Colearner Present" condition [F(1, 76) = 5.25, p < .03]

Participants in the "No Emotion Colearner" condition also rated their colearner as less trustworthy and intelligent than those in the "Cooperative Colearner" condition. Since credibility and intelligence are considered key in persuasion and motivation, it should come as no surprise that these participants did not perform as well in the post-experience evaluation. The index for measuring the perceived trustworthiness of the colearner character was created based on three 10-point Likert scale items describing the colearner character ("Honest," "Sincere," and "Trustworthy"). A factor analysis demonstrated that there was a single factor extracted, and a reliability test calculated revealed that the index could be considered as a reliable measure (Cronbach α = 0.82). A t-test revealed that the "Cooperative Colearner" condition (M= 5.72, SD= 1.76) and the "No Emotion Coleaner" condition (M= 4.28, SD= 1.88) that there was a significant difference between the conditions (equal variance assumed according to the Levene test). As can be seen in Figure 5, the cooperative colearner was perceived as more credible and trustworthy than the no-emotion colearner, t (49) = 2.28, p < 0.01.

In order to examine the perceived intelligence of the colearner character, an index, which consisted of three 10-point Likert scale items ("Smart," "Intelligent," and "Confident"), was created. A factor analysis showed that a single factor could be extracted from the three items, and a reliability test calculated for the three items demonstrated that the index could be used as a reliable measure (Cronbach α = 0.70). When the "Cooperative Colearner" condition (M= 5.04, SD= 1.93) and the "No Emotion Colearner" condition (M= 3.90, SD= 1.07) were compared, the t-test result (equal variance not assumed according to the Levene test) revealed that there was a significant difference, as can be seen in Figure 5. The "Cooperative Colearner" character received significantly higher ratings in terms of perceived intelligence, t (38.91) = 2.64, p < 0.05.

FUTURE DIRECTIONS

Now that we know colearners – even autonomous ones – can impact students' performance, we are looking forward to following up this experimental study to determine other characteristics of colearners that may also contribute towards enjoyment of the experience and learning gains. An overarching goal is to find out if it will be possible to design a colearner in the future that will maximize learning for every student it interacts with, regardless of age, culture, subject matter, preferences, or personality traits. Perhaps such as super-colearner is not feasible, yet we would be delighted to shed additional light into the characteristics of successful dyads in academic environments, real or virtual. Through this new line of research with pedagogical characters we may be able to realize the promise of personalized learning through companions, recommending a combination of colearner attributes to maximize enjoyment and achievement based on a short personality quiz and background profile.

There are many factors that difficult arranging and evaluating such matches in real-world classrooms: among them, students social networks and status differentials, heterogeneity of student responses and high levels of distractions. Heterogeneous groupings in classrooms are often perceived as detrimental for some of the group members, whether in terms of racial and social tensions, smaller performance gains, and additional distractions, among others (Carter and Jones, 1994). Yet in online teaching environments it may be possible to customize the colearner to best fit the needs of every learner, and to progressively adapt should these change.

Within our group we will continue to explore dimensions of the colearner, cautiously controlling for interaction effects among these. We are already planning to evaluate four of these dimensions shortly: personality traits, cross-cultural comparisons, effects of other types of social banter beyond cooperative comments and of the colearner's performance. As a first step, we have continued strengthening and adding value to our eSchool platform, so that future experiments will examine potential matches and mismatches of the colearner's personality traits with those of the participant. Earlier research has showed preferences for interactions with characters whose personality matches the experiment participants' (Reeves and Nass, 1996), and we would like to extend this research by evaluating whether students learn more when they are matched with the colearner or mismatched, even if their enjoyment of the experience is diminished.

A second direction that we are very interested in pursuing within our cross-cultural team is that of cross-cultural comparisons. As the Third International Mathematics and Science Study (Stigler et al, 1999) videos demonstrate, countries vary widely in their educational values and practices. While the experiment described above showed remarkable gains in learning and enjoyment for the cooperative colearner, it is possible that these results are culturally-specific. Given the strong collectivism of Japanese society, would students from more individualistic cultures respond as strongly to the "Cooperative Colearner" as the Japanese students in our sample?

A recent experimental study within our lab (Ju et al, 2005) seems to indicate that American students at least, also enjoy interacting with cooperative colearners more than with competitive colearners. Fourty-four undergraduates participated in a follow-up to our pilot study, using a web-based prototype similar to eSchool in their use of a colearner, avatar, and teacher. However, in this emulation of eSchool, the characters appeared on screen next to the chalkboard as stick figures, completely scripted and devoid of facial expressions. Rather than evaluating American idioms in a population immersed in their usage, this stick figure study focused on morse code lessons, and reported promising results for exploring performance variations in the colearners. This was one of the directions we were originally interested in pursuing: as with student dyads (Carter and Jones, 1994), participants with high-achieving colearners performed significantly better in this study than those paired with low achieving colearners. We are very interested in replicating these results, both those varying the colearner's performance and social banter, and hope through this research to enrich the understanding of how the interaction of these different characteristics of the colearners impact participants' learning and enjoyment. Seeking to build a robust corpus of characteristics of colearners, in our next experiment we will explore combinations of cooperative and competitive colearners with introverted and extroverted traits, to determine possible interactions between these two characteristics.

In terms of the cross-cultural direction, while the stick-figure study holds promise, rather than conducting experiments in multiple worldwide sites to determine cultural preferences, we are looking at abstractions from the rich literature of the international math and science education comparative studies (Stigler et al, 1999), as well as psychology and corporate training (Hofstede, 2003) to determine which aspects or dimensions of cultures may be applicable to, and general enough for, our educational goals.

CONCLUSION

The experiment reported in this paper, as well as those we hope to conduct shortly, have three inherent limitations that we would like to resolve gradually. Firstly, a one-time interaction may show an immediate spark in the learning gains that may not be maintained. We, as designers of promising educational software, hope it is indicative of long-term learning and transfer, and would like to re-evaluate the students that interact with eSchool in future experiments several days and weeks after the initial interaction, to determine these potential longer term learning gains. Because motivation effects can impact attainment, we are also very interested in a longitudinal study, where students would interact through the eSchool environment for several weeks, perhaps as part of a college course. If these interactions were voluntary for a sample of the subject population, we could explore whether colearners make the system enticing enough for students to progress on their own.

Secondly, we are considering how to best expand the colearner paradigm to other domains where the social aspect of our interactions with emotional characters can be leveraged, extending it beyond language learning. As mentioned, pedagogical characters have been successfully deployed in middle school curricula applications (Lester et al, 1997; Moreno et al, 2000; Biswas et al., 2004), oral storytelling (Kehoe et al, 2004), corporate training (Extempo, 2004), health behavior change interventions (Bickmore et al, 2004), and even military instruction (Johnson et al, 2004). We are eager to explore other domains where characters offer a unique advantage to traditional drill-and-practice software, motivating and entertaining students through their emotions and improvisational behaviors. We hope to replicate the colearner effects as we break-free from the classroom emulation into richer environments, where other interactive dimensions can be explored.

Among the suggestive findings we report are the implications for characters beyond pedagogical domains. Given the gains in enjoyment, credibility and perceptions of intelligence, character designers in domains where these three areas are critical may want to consider adding a cooperative dimension to their characters. From information kiosks to customer service representative, help and sales characters could all benefit from supporting their clients through cooperative behaviors.

Lastly, the world of pedagogical characters has rarely been as populated as in our application, yet we would like to explore interactions beyond the dyad, as well as those where the user is implicitly embodied. By evaluating the effects of the avatar's presence on social exchanges and achievement we hope to grow our understanding of how colearners improve learning environments, and to translate those findings to applications with multiple colearner characters. While our innovative focus thus far has been on dyadic interactions, the educational literature suggests that small group learning may be as productive, if not more. Nowadays, most software platforms and applications are capable of handling several characters operating simultaneously, which brings closer the potential for future evaluations with multiple colearners. We welcome the challenge of replicating the achievement and enjoyment gains colearners bring without losing our human participants in the virtual melee.

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Cognitive Tutoring of Collaboration: Developmental and Empirical Steps Towards Realization

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Abstract. In this paper, we describe developmental and empirical steps we have taken toward providing Cognitive Tutoring to students within a collaborative software environment. We have taken two important steps toward realizing this goal. First, we have integrated a collaborative software tool, Cool Modes, with software designed to develop Cognitive Tutors (the Cognitive Tutor Authoring Tool). Our initial integration does not provide tutoring *per se* but rather acts as a means to capture data that provides the beginnings of a tutor for collaboration. Second, we have performed an initial study in which dyads of students used our software to collaborate in solving a classification / composition problem. This study uncovered five dimensions of analysis that our approach must use to help us better understand student collaborative behavior and lead to the eventual development of a Cognitive Tutor for collaboration. We discuss our plans to incorporate such analysis into our approach and to run further studies.

Keywords: Collaborative learning, Cognitive Tutors, jigsaw design, spatial effects on problem solving

INTRODUCTION

Intelligent Tutoring Systems (ITS) have long been used to provide one-on-one (machine-to-student) instruction (Wenger 1987). We are interested, however, in using a software tutor to instruct *multiple* students collaborating on a single problem. There have been steps toward providing tutoring in a collaborative environment (e.g., Goodman *et al*. 2003; Suthers 2003; Lesgold *et al*. 1992), but many difficult challenges remain. For instance, the space of possible actions among collaborating users is huge for even the simplest of problems, thus making the analysis of learner behavior much more difficult for collaborative tasks than for the single-student case.

As a step toward addressing the complexities of a collaborative environment, we have created a tutor-development methodology that leverages actual problem-solving data not only to guide ITS design, as has been done in past work (e.g., Koedinger and Terao, 2002), but also to contribute directly to tutor implementation (McLaren *et al*. 2004a; McLaren *et al*. 2004b). Using this approach, called *bootstrapping novice data (BND)*, groups of collaborating students attempt to solve problems with a computer-based tool. While they work, the system records their actions in a graphical representation that combines all of the groups' solutions into a single graph that can be used as the basis for building a tutor and analyzing the collaboration. Our initial BND implementation is realized through the integration of a collaborative modeling tool, Cool Modes (Collaborative Open Learning and MODEling System) (Pinkwart 2003), and a tutor authoring environment, the Cognitive Tutor Authoring Tools (CTAT) (Koedinger *et al*. 2004).

Our ultimate research aim is to develop better support for collaborative learning through cognitive tutoring. In this paper, we describe two steps we have taken toward realizing this ambition: (1) an initial implementation of the BND methodology and (2) a study using the BND approach, including the results and the implications for further development of the methodology. The study we have performed reveals some interesting aspects of the way dyads solved a particular collaborative problem. More importantly, it has pointed us in the direction of improving our implementation of the BND methodology and realizing cognitive tutoring in a collaborative environment.

In our initial implementation of the BND methodology, depicted in Figure 1, Cool Modes (shown on the left) provides the graphical user interface, including a shared workspace that all collaborators in a session can view and update, a palette with objects that users can drag onto the workspace, a chat area, and a private workspace. Cool Modes sends messages about students' actions (e.g., "create an IS-A link") to CTAT's

Behavior Recorder (also referred to as the "BR" and shown on the right of Figure 1), which stores the actions in a *behavior graph.* Edges in the graph represent student actions and paths through the graph represent attempted solutions to the problem. The current approach keeps track of the number of times actions are taken by the various collaborating groups and presents these "traversal counts" on the edges of the behavior graph, e.g., 3 student dyads took the action from the "start state" Classification-Composition to State1. Using CTAT, a tutor author can subsequently transform the generated behavior graph into a *Pseudo Tutor*, or problem-specific tutor (Koedinger *et al.* 2004), by adding or deleting edges, labeling correct or buggy behavior, and adding hints to the edges. To use the finished graph as a tutor, the BR is switched to "model-tracing" mode in which student actions are compared to the graph, instead of recorded, and error messages and hints are delivered to the student. While our ultimate aim is use this approach to provide cognitive tutoring within Cool Modes, as well as other collaborative environments, our initial focus is somewhat more modest: We want to analyze data that was collected using the BND methodology to help us better understand both collaborative behavior and how we can enhance the BND methodology to provide more useful analysis of that behavior. The preliminary study that we have performed is an example of such an analysis.

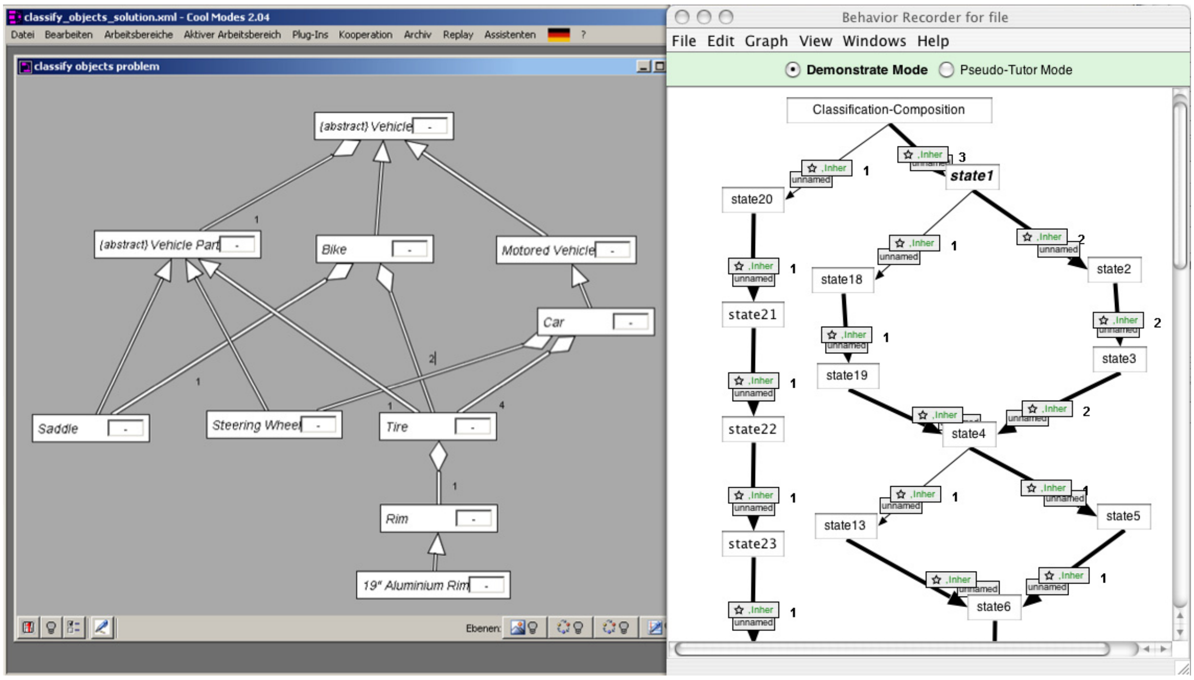

Figure 1: The student's view of the integrated Cool Modes (left) and the Behavior Recorder (right) environment. This shared Cool Modes workspace is from a vehicle classification / composition task that was completed by a dyad of collaborating students. The behavior graph at right shows the amalgamated solutions of different collaborating groups of students.

DESCRIPTION OF THE STUDY

The research question in the preliminary study was whether, in a graphical problem-solving domain, an organized arrangement of objects leads to quicker and better collaborative solutions than a disorganized arrangement. We also wondered whether student rearrangement of the objects facilitates quicker and better results and how this rearrangement might be conducted in a collaborative scenario. To explore these questions and test how the BND methodology might be a useful analysis tool, we assigned 16 students to 8 dyads and asked each dyad to solve an object-modeling problem using the Cool Modes / BR integrated system (one subject was a class assistant). The objects in the given problem were vehicles (e.g., "Car") and parts of vehicles (e.g., "Tire"). The student dyads were asked to relate the objects using classification and composition links. The students were volunteers from a "Modeling Techniques in Computer Science" course at the University of Duisburg, Germany. Seven of the students (pairs 6, 7, 8 and one in pair 5) had had previous experience with Cool Modes. All students received approximately 5 minutes of instruction on how to use the system before the experiment. The student pairs worked at separate workstations, back-to-back in the same room. They shared a single Cool Modes workspace.

To specify IS-A (i.e., classification) and PART-OF (i.e., composition) links between objects in the workspace, the students used the Unified Modeling Language, a graphical modeling technique. To stimulate collaboration we used an unequal resources design akin to jigsaw experiments (Aronson et al. 1978). One student was provided with IS-A links only and one with PART-OF links only, so that no student could solve the problem alone. Students communicated by typing statements into a chat box. The only other communication permitted was the actual composition and repositioning steps taken by the students in the shared workspace.

The 8 groups were randomly assigned to two experimental conditions. In Condition 1, pairs attempted to solve a problem in which related objects were close to one another, providing an organized visual display of the final network. For example, the two abstract classes “Vehicle” and “Vehicle Part” were located near the top of the visual space, and most of the subclasses were located near their respective super classes. In Condition 2, pairs solved a problem for which the objects were positioned in the workspace without any clear organizational principle.

STUDY RESULTS AND ANALYSIS

All 8 dyads completed the task. Students’ solutions can be divided into three categories: ***good*** solutions (groups 5 and 8), ***incomplete*** solutions (groups 2, 6, and 7), and ***poor*** solutions (groups 1, 3, and 4). All three poor solutions were in the disorganized condition, and two of the incomplete solutions were in the organized condition. While one of the good solutions was in the organized condition, one was in the disorganized condition. There were negligible differences in the time required to complete the task between the different solution categories. The informal results suggested that a clearly organized problem state does not necessarily lead to quicker and better solutions than a disorganized problem state, but does lead to different types of errors. It is of course impossible to draw statistical conclusions about the relationship between the solutions and starting conditions with such a small sample size, but we nevertheless have made some interesting informal findings. We now describe those findings.

The conceptual distinctions between good, incomplete, and poor solutions were related to the errors committed in solving the classification / composition problem. In the good solutions, errors reflected misunderstandings about the meaning of classes. Otherwise, students correctly divided the objects into subclasses and super classes and correctly placed the inheritance and composition edges. In the incomplete solutions, students only connected one inheritance or composition link from each class. As a result, they had too few links, and left out key relationships. In the poor solutions, students would often connect a class to multiple ancestor nodes of the same lineage. For example, in Group 3, students connected "Car" to both "MotorVehicle" and "Vehicle." The poor solution groups also typically created too many edges and were logically inconsistent about the connection decisions they made.

Solutions can also be characterized by the way students tended to move nodes in the shared workspace. In the good solutions, the students separated the two abstract classes, placing one at the top of the workspace and the other at the bottom. IS-A and PART-OF links flowed in opposite directions and crossed only when necessary. Objects were organized in rows that reflected their level of abstraction. In the incomplete solutions, the two abstract classes were placed relatively close to one another, all links pointed in one direction, and there were no crossed links. The objects tended to be clustered together and were organized into fewer rows than in the good solutions, but the rationale behind the organization wasn't as clear. Finally, the poor solutions had the abstract classes positioned without an obvious rationale. They had much longer edges pointing in all directions and frequently intersecting with one another. As a result, the poor groups tended to use the entire shared workspace.

We then analyzed the processes associated with the development of each solution. While working on the problem, students could take three types of actions: *chat* actions, "talking" to a partner in a chat window, *move* actions, repositioning an object in the shared workspace, and *creation/deletion* actions, creating or deleting edges. Solution types showed differences in collaborative and task-oriented behavior. In terms of collaboration, the students with the good solutions had different approaches. Group 8 worked completely collaboratively. Members would take turns moving and creating objects and for a given group of objects, one member would reposition objects while the other would create the edges. Conversely, the members of Group 5 worked completely in parallel, coordinating their actions only to correct their partner's mistakes. In the incomplete and poor groups, pair members shared the work. The poor groups were informal in their turn taking, while students in the incomplete groups would alternate taking the initiative. With the exception of Group 5, groups decided on their actions using the chat window and ensured that both members agreed on the actions being taken.

The three solution groups coordinated phases of chatting, moving, and creating/deleting differently. In the good solutions, the approaches of two pairs were dissimilar. Group 8 collaborated by alternating chat phases, move phases, and creation/deletion phases. Group 5 alternated between move phases and creation/deletion phases, and primarily communicated visually. In both groups, adjacent phases referred to the same objects and levels of abstractions, displaying a coherent problem-solving strategy. Both pairs were the only groups to have more move actions than chat actions. The incomplete groups had fewer move actions, longer phases of chatting, and fewer deletions. They adopted the inefficient strategy of discussing many future actions, creating a single edge, and then repeating the discussion. On the other hand, they would consistently reorganize objects before creating edges, which may have contributed to the tree-like organization of the classes. The poor groups engaged in long phases of chatting or moving, but showed less coherence between the objects they were discussing, objects they were creating, and objects they were moving. They deleted a lot of edges and tended to create particular edges before repositioning them. This disorganized approach probably led to the conceptual and visual disorganization of their final solutions. Another difference was in terms of the selection of objects: Both the good and the incomplete solutions would focus on objects based on their level of abstraction; they would manipulate a given superclass and all its subclasses, and then move on to another group of objects. On the other hand, students in the poor solutions appeared to let the problem organization guide their actions. They would draw edges based on classes that were close to one other in the shared workspace, rather than classes that were semantically related. Differences in object selection probably related to differences in the consistency of the final solutions.

These results indicate that we should focus on five elements when evaluating students' performance (at least on this particular task): *conceptual understanding, visual organization, task coherence, task coordination,* and *task selection,* (see Table 1). These elements were chosen because they represent different relevant aspects of student action that appeared to inform groups' solutions. Students within each solution type (good, incomplete, and poor) tended to make the same types of mistakes within each of these categories.

Conceptual understanding refers to a pair's ability to correctly place the inheritance and composition edges, while visual organization refers to a pair's ability to visually arrange the classes and edges in an appropriate manner. These two elements are linked; conceptual understanding of the problem was often reflected in the visual organization, and therefore conceptual steps tended to parallel organizational steps. For example, students in the incomplete solution groups appeared to believe that they could create only one inheritance or composition link extending from each object, and their solutions thus tended to take on rigid tree structures.

	Conceptual Understanding	***Visual Organization***	***Task Coherence***	***Task Coordination***	***Task Selection***
Good Solutions	Translation mistakes	Based on abstractions	Adjacent phases referred to the same objects	Balanced phases and work distribution	Based on abstractions
Incomplete Solutions	Overly restricted definition of super class / subclass relationships	Based on a rigid, tree-like structure	Chat phases referred to far more objects than subsequent phases	Strict turn-taking and overly long chat phases	Based on abstractions
Poor Solutions	Inconsistent definition of super class / subclass relationships	Disorganized	Little correspondence between selected objects in adjacent phases	More informal turn taking and overly long phases (particularly of deletion)	Based on proximity

Table 1: Solution Types and Elements of Analysis

Task coherence, task coordination, and task selection reflect student strategies for collaborating on the problem. Task coordination refers to skills in coordinating actions, without reference to the content of the actions. It includes distributing the work among group members, and spending appropriate amounts of time in each phase. The good groups exhibited successful task coordination, in part because they spent more time moving objects than talking about them. Task coherence refers to the appropriateness of the content of student actions. Students in the incomplete groups showed poor task coherence by chatting at length about many different links and then creating a single link. Task selection refers to a student's ability to set subgoals for solving the problem by drawing edges between classes in a sensible order. A breakdown in task selection leads to disorganized and incoherent solutions, as seen in the poor group. These three skills should be assessed by looking at the problem-solving process.

IMPLICATIONS FOR IMPROVING THE BND METHODOLOGY AND CONCLUSIONS

One of the key goals of this study was to determine how to enhance the BND methodology to provide more helpful data and analysis. In theory, the BR should be able to facilitate analysis of all the skills from Table 1. However, these five elements are not supported in the current BR, making it difficult to classify behavior and provide tutoring support. In an attempt to produce convergent paths in the behavior graphs, we restricted input to the BR to creation and deletion actions. Unfortunately, analyzing creation and deletion appears too limited to be useful. Although the BR records sequences of actions at a single level of generality, the nature of this problem indicates that student skills at different levels of abstraction need to be addressed, and the BR needs to be able to create hierarchies of behavior graphs.

We intend to address this problem by modifying the BR to support recording at different levels of abstraction. Single chat, move, or creation/deletion actions, made by a particular user and referring to a particular object, are at the lowest level of abstraction. Separate behavior paths can be generated for the creation/deletion and move actions, and used for analyzing the conceptual understanding and visual organization. The middle level of abstraction involves the analysis of *phases* of action, or chains of the same type of action, and can deal with task coherence and task coordination. The highest abstraction level addresses sequences of phases, or the characteristics of the current phase in relation to previous and subsequent phases. Skills related to task selection will be evaluated and supported at this level. An approach to classifying actions and action sequences in Cool Modes has been described in Harrer and Bollen (2004), and can be used to process actions at different levels of abstraction.

Given these changes, we believe the modified BR will be a much more effective tool for analyzing collaboration and providing tutoring support in future experiments. Besides the preliminary study we have already performed, we plan to perform two more experiments in the near term. In these studies, we will test how students collaborate to solve a Petri Net problem. We wish to determine how well the five elements of analysis we have uncovered generalize to other graphical collaboration tasks and to less structured problems. We then intend to enhance the BND methodology to allow us to compare and classify student problem solving strategies. The resulting annotated behavior graphs will provide the basis for cognitive tutor development within Cool Modes.

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CSCL Scripts: Modelling Features and Potential Use

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Abstract. The design of collaboration scripts is a new focus of research within the CSCL community. In order to support the design, communication, analysis, simulation and even execution of collaboration scripts, a general specification language to describe collaboration scripts is needed. In this paper, we analyse the suitability and limitations of IMS LD for modelling collaborative learning processes. Based on the analysis, we propose a CSCL scripting language. This paper presents the conceptual framework of this modelling language and the underlying design ideas. Furthermore, two developed CSCL script authoring tools are briefly described. Finally, we discuss potential types of usage and system support possibilities of CSCL scripts.

Keywords: IMS LD, CSCL scripting language, CSCL script, CSCL script authoring tool

INTRODUCTION

According to O'Donnell & Dansereau (1992) a collaboration script is a set of instructions specifying how the group members should interact and collaborate to solve a problem. The term "script" was initially used in schema theory by Schank and Abelson (1977). According to schema theory, a script is a mental structure representing the people's knowledge about actors, objects, and appropriate actions within specific situations. When group members interact with each other, a shared script can help them to reduce the uncertainty about coordination efforts (Mäkitalo et al., 2004), because they know how to behave and what to expect in particular situations. By providing learners with a collaboration script, it is conceivable that learners can also aim at cognitive objectives like fostering understanding or recall. Additionally, collaboration scripts might also support the development of meta-cognitive, motivational, or emotional competencies (Kollar et al. 2003). A collaboration script is normally represented in the learners' minds (internal representation) and can be represented somewhere in the learning environment (external representation). Because we focus on using collaboration scripts in computer settings, we are interested in representing collaboration scripts in a formal way so that they can be handled by the computer. Such a computational representation of a collaboration script is called a CSCL script.

The conceptual components of a collaboration script and their relations have been discussed in literature (Dillenbourg 2002, Kollar et al., 2003). However, a general modelling language for formalising collaboration scripts is still missing. Furthermore, there is no corresponding authoring tool for CSCL practitioners to create, reuse, integrate, and customise CSCL scripts without a high overhead of technical knowledge. As a first step in the direction of a CSCL scripting language we investigate existing learning process modelling languages. The most important attempt in the current discussion in this direction is IMS Learning Design (IMS LD), a standard published by the IMS consortium based on the Educational Modelling language (EML) developed by the Dutch Open University OUNL (Koper, 2001). It is claimed that IMS LD can formally describe any design of teaching-learning processes for a wide range of pedagogical approaches (Koper, 2001, Koper & Olivier 2004). This modelling language has strengths in specifying personalised learning and asynchronous cooperative learning. However, IMS LD provides insufficient support to model group-based, synchronous collaborative learning activities. Caeiro et al. (2003) criticised IMS LD regarding CSCL purposes and suggested a modification and extension of the specification. This modification and extension is just restricted in role-part and method part. Hernandez et al. (2004) suggested adding a special type of service, called "groupservice" to extend the capacity of IMS LD. Such an extension at service level, rather than at activity level, cannot appropriately capture the characteristics of collaborative learning activities.

The research work presented in this paper aims at developing a scripting language for formalising CSCL scripts and exploring their potential types of usage and system support possibilities. In the first part of this paper, we intend to clarify the limits of IMS LD when working on a computational methodology for collaborative learning process scripting. Based on the analysis, we propose a scripting language to facilitate modelling collaborative learning processes. Rather than a systematic description of the CSCL scripting language, we present it by focusing on how the identified problems of IMS LD for CSCL scripts are solved. Then we briefly describe two script authoring tools based on the CSCL scripting language. In the second part of this paper we try to address the current misbalance between the broad acceptance of CSCL scripts as being an innovative and relevant topic of research into learning technologies, and the weak definition of potential forms of usage of such representations in learning situations. The most frequent answer to this question is a CSCL script as a source for a configuration tool to support runtime environments during the learning process. As we explain in our second part, such a scripting language will be helpful for CSCL practitioners (e.g., teachers and students) in design phase (e.g. editing, communicating, predicting, simulating) and in the execution phase (e.g. configuration, monitoring, scaffolding).

INVESTIGATING THE CAPACITY OF IMS LD FOR FORMALISING COLLABORATIVE LEARNING SCRIPTS

A collaborative learning experience can be described by a collaboration script. Many collaboration scripts have been designed, tested, and even embedded in CSCL applications (e.g., Hoppe & Ploetzner 1999, Guzdial & Turns 2000, Miao et al. 2000, Pfister & Mühlpfordt 2002). The European MOSIL project (MOSIL, 2004) worked on generalised CSCL scripts. One example discussed in the MOSIL project is the *maze* script, which is described in detail in (Jansen et al., 2004). In this script student groups try to develop strategies how to escape out of an arbitrary maze. A typical use case of the script is described below.

First the teacher gives a short introduction about the structure of the learning task and then divides the class (24 students) into 6 groups of four (activity 1). Toni and Darina form group 1 together with two other students. They can use a little lego robot in a physical maze and a computer simulation with a robot in a maze. Toni and Darina are the “strategy developers” and the other two students are the “maze builders” to test the strategies (so called rule sets). Strategies and mazes can be stored on a central server (activity 2). Then each group in turn presents their developed group results. As a group speaker Toni presents their first results (activity 3). Now all groups are allowed to access the other groups work results. The roles within the group have switched, so Toni and Darina now are the “maze builders” trying to improve the groups’ mazes so the other groups’ strategies will not help to escape out of them. Meanwhile the other two students are working as the “strategy developers”. A competition has started to find out which group develops the best strategies and mazes (activity 4). Finally the group that wins in the competition shows their achieved results (activity 5). This script can be applied when there is a thesis – antithesis (rule set- against-maze or pro-against-contra-argumentation) situation which can build the basis for a competition between groups. In the following discussion we will refer to the features of the described script.

When using IMS LD to formalise collaboration scripts, we see several major difficulties and challenges:

- Modelling groups
- Modelling artefacts
- Modelling dynamic features
- Modelling complicated control flow
- Modelling varied forms of social interaction

This will be discussed in more detail below by referring to the maze script explained above.

1) Modelling group work with IMS LD confronts with the problem how to model multiple groups with the same role and the dynamic changes of groups. IMS LD enables to define multiple roles. Each role can be played by multiple persons. When investigating, we found that in many cases the notation of “role” can be used to model groups for CSCL scripts. However, by using IMS LD it is very difficult to specify how a group work pattern is assigned to several groups working in parallel and how sub groups can be defined within these groups (like needed in activity 2 and 4). If each group/subgroup is defined as a role, the designer has to define a list of roles representing multiple groups (e.g., maze builder 1, …, maze builder 6). The problem of this solution is that the number of groups in a run is inpredictable during the modelling phase. If only one role (e.g., maze builder) is defined for all subgroups building mazes, then all persons who build mazes will have the same role. The problem of this solution is the information about groups/subgroups will miss and the run-time system cannot support inter-/intra-group collaboration appropriately. In addition, in IMS LD roles are assigned to persons before running a unit of learning and these assignments keep unchanged within the life cycle of the run. However, in some situations (e.g., in activity 1) groups are formed and group members are assigned after the start of the process execution. Therefore, in some situations, the notation of role cannot meet the requirement to model groups.

2) A second major difficulty while modelling CSCL scripts with IMS LD we see in modelling artefacts. In learning processes, actors usually generate artefacts such as a vote, an answer, an argument, or a design. In IMS LD, an artefact can be modelled as a property, e.g. of a person or a role, which creates the artefact. This property can be used to maintain information such as the outcome of a person or a role and to support personalised learning. In collaborative learning processes, an artefact is usually created and shared by a group of people. It is normally used as a mediation to facilitate indirect interaction among group members. It may be created in an

activity and used in other activities like an information-flow. For example, in the maze script the different sub groups produce, reuse and improve rule sets and maze definitions. In order to support group interaction, an artefact should have attributes such as artefact type, status, created_by, creation_activities, contributors, consume_activities, current_users, and so on. By using IMS LD to model an artefact as a property, one has to model all attributes of the artefact as properties as well. These properties should be defined as a property-group with many restrictions. Such a complex definition cannot be intuitively understood. It will be very difficult to model dynamic features even for technical experienced designers, because the limited data-types of properties and many references make it very complicated to handle artefacts. In addition, it is difficult to model a collective artefact, because IMS LD does not support array-like data-types for a property. For example, it is inpredictable how many rule sets are developed by a group in activity 2. Furthermore, an artefact as a maze definition may have a complex data structure and has to be handled by using specific application tools. IMS LD has no means to specify the relation between artefacts and tools.

3) A third major difficulty while modelling CSCL scripts with IMS LD occurs when modelling dynamic process aspects. IMS LD provides two categories of operations on process elements: read-access operations ("getters") to get the state of process elements (e.g., users-in-role, datetime-activity-started) and write-access operations to change the state of process elements (e.g., change-property-value, hide/showe elements, and send notification) to model dynamic features of learning processes. For modelling collaborative learning processes, more write operations are needed. For example, during the first activity, the teacher creates groups/subgroups and assigns group members. An example of needed read-operations can be found in activity 3 "number-of-role-members" which can be used as the upper limit of a loop control variable to model multiple times of presentation performed by each working group in turn. At least, process element operations concerning our proposed extensions like group and artefact should be extended.

4) A fourth major problem is how to model complex process structures. IMS LD provides *play, act, role-part,* and *activity-structure* to model structural relations at different levels. Primarily linear structured learning/teaching processes with concurrently executable activities can be modelled. However, as Caeiro et. al. (2003) pointed, the linear structure of a play with a series of *acts* introduced a great rigidity while modelling network structures. Although it is possible to model non-linear structural relations among activities by using conditions and notifications, the specification of a collaborative learning process might be very complicated and confusing. In addition, it is very difficult to model a control flow associated with complicated combination of process instance thread splitting and synchronisation. Such a situation must happen in collaborative learning processes although the control flow of the maze script can be modelled by using IMS LD.

5) The last difficulty we want to stress in this paper occurs when modelling varied forms of social interaction. IMS LD uses a metaphor of a theatrical play to model learning/teaching processes. A play consists of a sequence of acts and within an act there is a set of role-parts. These role-parts can run together in parallel. Role-parts enable multiple users, playing the same or different roles, to do the same thing or different things concurrently on the same act. For example, while each student reads the same article, the teacher prepares presentation slides. If a group of people performs a synchronous activity, IMS LS enables them to use a conference service and provides no means at activity level to support collaboration. In collaborative learning processes, it is quite usual that people with the same or/and different roles perform a shared activity through direct or indirect interaction. While making the joint effort, people with different roles may have different rights to interact with other roles and the environment. In particular, it can not be clearly modelled by using IMS LD whether and how people collaborate, because people may work in a variety of social forms: Individually, in an informal group, in sub-groups (e.g., in activity 2), in a group as a whole (e.g., in activity 1), or in a community.

AN APPROACH TO FORMALISE CSCL SCRIPTS

In order to enhance effective collaboration designs, we have developped a CSCL scripting language to formalise collaboration scripts. Because of the limited space of the paper, rather than a systematic description, we briefly present the CSCL scripting language by explaining the core concepts and their relations. Then we focus on describing how the identified problems of IMS LD for CSCL scripts are solved in our scripting language.

CSCL Scripting Language

In this subsection, we briefly present the core concepts and their relations of the CSCL scripting language.

A *CSCL script* is a specific learning design which emphases collaboration. A CSCL script contains contextual information that applies to other elements within the process. As shown in Figure 1, a CSCL script consists of a set of *roles*, *activities*, *transitions*, *artefacts*, and *environments*. A CSCL script has attributes such as learning objectives, prerequisites, design rationale, coercion degree, granularity, duration, target audience, learning context, script-specific properties, and generic information (e.g., id, name, description, status, creation date, and so on). The attribute "design rationale" enables to express and communicate the design ideas and underlying pedagogic principles. The values of the attribute "coercion degree" represent different degrees of "informedness". CSCL scripts with different coercion degrees have different usages, which will be discussed later in the paper. If a lower-grained CSCL script is embedded in a higher-grained CSCL script, the mappings between the roles, properties, and artefacts of two CSCL scripts should be specified. A *role* is used to distinguish users who have different privileges and obligations in the processes described in the CSCL script. Both *persons* and *groups* can take a role. A group can have subgroups and person members. An *activity* is a definition about a logical unit of task performed individually or collaboratively. There are three types of activities: atomic activity, compound activity, and route activity. A compound activity is decomposable consisting of a set of networked activities and even other scripts. A *transition* specifies a temporal preceding relation between two activities. An *artefact* may be created and shared in and/or across activities as an intermediate product and/or a final outcome. An *environment* can contain sub-environments and may contain tools and contents. A *tool* may use artefacts as input parameters and/or output parameters. A *content* is a kind of learning objects which exist and are accessable. An *action* is an operation and may be performed by users during an activity or by the system before/after an activity. A *property* may be atomic or may have internal structure. An *expression* may use properties and other expressions as operands. Like IMS LD, a *condition* refers to a condition clause which is defined as if-then-else rule consisting of a logical expression and actions, transitions, and/or other conditions. Actions, properties, expressions, and conditions have very complicated relations with other process elements (e.g., scripts, roles, activities, artefacts, persons, groups, environments, and so on). For example, an action may use process elements as parameters and change the values of attributes of certain process elements. Such relations are not drawn in this diagram in order to keep the diagram simple and readable.

Using the scripting language to formalise a collaboration script means specifying how persons and/or groups, playing certain roles, work collaboratively towards certain outcomes (partially as artefacts) by performing temporally structured activities within environments, where needed tools and content are available. Actions, properties, expressions, and conditions are useful to modelling more complicated, dynamic control-flow and information-flow in collaborative learning processes.

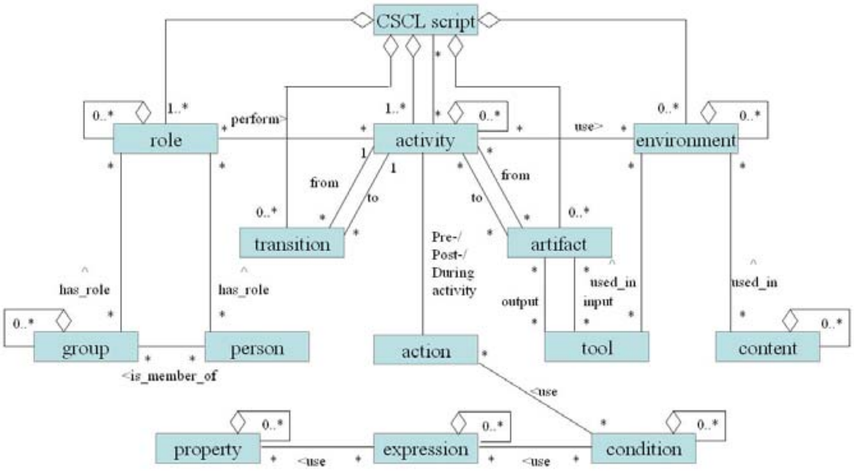

Figure 1: Core modelling elements and their interrelation

Solutions

In this subsection, we focus on presenting our solutions to the identified problems of IMS LD for CSCL scripts. We refer here to the Maze script to show the feasibility of our modelling elements to address these problems.

Explicitly introducing groups

The introduction of a group element enables to model group based collaboration intuitive and simple. In our CSCL scripting language, a group is modelled by using attributes such as name, max-size, min-size, person members, super-groups, sub-groups, engaged roles, form-policy, disband-policy, dynamic/static, and run-time information. In addition, local-/global group properties are added for capturing group characteristics. A group can be assigned to a role. Therefore, when a group role is defined like "maze builder" in maze script, the activity 2 is assigned to this role just once no matter how many groups will play this role at a run. On the one hand, a group can have subgroups and form a hierarchically structured organisation (a directed-acycle-graph). Any change in the organisation has no affect on the definition of the role in scripts. On the other hand, re-definition of roles in scripts does not effect on organisation. A question raises that when to model a group and when to use a role. From our perspective, some roles are organisation-oriented definitions like students and staff. Others are behaviour-oriented role such as meeting chairman and tutor. It would better to model an organisation-oriented role as a group role and to model a behaviour-oriented role as a person role.

Explicitly introducing artefacts

The *artefact* element does not exist in the IMS LD specification. As we explained already, the usage of artefact elements enables to model within CSCL contexts much more intuitive and easier than to model the same process within IMS LD, because some burden for designers to handle technical tasks are released by providing built-in mechanisms. In our language, an artefact, such as a Maze rule set, is treated as a file which can be a MIME-type or user-defined type. The attributes of an artefact contain generic information (e.g., title, description, type, status, URL, sharable, and aggregated), association information (e.g., creation_activities, consume_activities, and default_tool), and run-time information (e.g., created_by, creation_time, contributors, last_modification_time, current_users, locked_status, and so on). An artefact and its status will be visible in the environment of the creation-/consume- activities at run-time. The specification about the relations between artefacts and tools will help the run-time system to pass to/from artefacts as input/output parameters to tools automatically at run time. Some expressions and actions related to artefacts should be added for mediating group work such as get-current-users-of-artefact and change-artefact-status. The artefact-specific properties may be useful to model a specific feature of an artefact. As an aggregated artefact, it is possible to append collective information to the same file.

Extending actions and expressions

An *action* is a generic and powerful mechanism to model dynamic features of a collaborative learning process. Some actions are components of the CSCL scripting language that can be executed directly by the run-time system. In addition, we add an action declaration mechanism for experts to define a procedure by using the CSCL scripting language. In order to support the definition of complicated procedures, we add a "collection" data type and a loop control structure. The defined procedure can be interpreted by the run-time system into process element operations, and in turn, into executable code. Therefore, complicated actions can be defined by using an action declaration and assigning the parameters needed. IMS LD provides a limited set of actions such as property operations, showing/hiding entity, and notification. The action notation we introduced provides a unified form of operations including not only actions defined in IMS LD but also commonly used operations concerning script, activity, artefact, role, group, person, transition, environment, and their relations. An example action is enabling students to access all the other groups work results. Another example action is exchanging the role assignment between "maze builders" and "rule set developers" before the start of activity 4 in the example script. An *expression* is defined as it is in IMS LD: there some read operations can be used as operands in expressions like "is-member-of-role", "datetime-activity-started", and "complete". However, it is necessary to add read operations to support collaboration such as "is-all-role-members-online" and "artefact-contributors". Furthermore, corresponding to the action declaration, we add an expression declaration mechanism for experts to define complicated expressions which could be reused by normal teachers and students.

Introducing transitions and routing activities

We partially accept the suggestion of Caeiro et al. (2003) to introduce transitions and routing constructs recommended by the Workflow Management Coalition (WfMC home page). Because interactions of person-to-person, group-to-group, and role-to-role and splitting and synchronisation of process threads never restricted at higher levels, we have to use such a mechanism not only at play level but all possible levels in order to model the arbitrary complicated structural relations among activities.

Using activity-centred methods to assign roles

We give up the metaphor of a theatrical play and the role-part method. Instead, we use an activity centered role assignment method. In CSCL scripting language, for modelling an activity, the attributes are defined to specify engaged roles, used environments, input/output artefacts, transitions and restrictions, pre-/post-/during activity actions, user-defined activity-specific properties, completion-mode, execution-time, completion-condition, mode of interaction, social plane, interaction rules, generic information, and simulation information. Some attributes are important for designers to model collaborative processes and some for the run-time system to configure collaborative learning environments appropriately for users. For example, the possible values of social planes are: separately with a certain role, individually with a certain role, collaboratively with one and/or multiple roles, collaboratively in subgroups with a certain role, and so on. If the choice is "separately", the run-time system will create an activity instance for each user who reaches the activity. If anyone completes his activity (e.g., submitted a final rule set), all activity instances terminate. The "individually" means that the run-time system will create an activity instance for each user. The run-time system synchronises access to the following activity by continuously checking whether all users have already completed the current activity. In comparison, the run-time system based on IMS LD typically handles this situation defined by using the role-part method. The choice of "collaboratively with one and/or multiple roles" makes the run-time system create only one activity instance and a session facilitating collaboration (e.g., in activity 1). The semantics of the value "collaboratively in subgroups with a certain role" is that the run-time system creates an activity instance and a session for each sub-group and the members of each sub-group can have a shared activity workspace. The run-time system synchronises access to the next activity when all subgroups finish their work (e.g., in activity 2). Another example is the attribute "interaction rules". An interaction rule specifies under which condition which role can (not) perform which actions. For example, in activity 1, the tutor can perform the actions to create (sub)groups and assign group members. In activity 4, students can access strategies and mazes created by other groups. Such information can be used by the run-time system to automatically provide corresponding awareness information and to avoid work overload. It is of importance to provide the necessary information to the right people at right time. In short, interaction rules explicitly specify different responsibilities of different roles in a collaborative learning activity.

CSCL SCRIPT AUTHORING TOOLS

In order to support the effective formalisation of collaboration scripts, we are two tools using different representation perspectives on CSCL scripts: a tree based and a diagram based perspective. The tree-based view provides both an overview of the hierarchical structure and a view of semantic details. The diagram-based view is suitable for specifying processes with layered, more complicated control flow structure intuitively. Both tools are based on the CSCL scripting language described in the last section. They enable designers which are not technical experts to understand and design collaboration scripts. Both tools are suited to capture the essential concepts of the Maze script. This is partially shown in figures 2 & 3. The scripts can be translated from/into XML-formatted CSCL scripts automatically by the tools. A CSCL script can be created, saved, validated, and delivered. For supporting different usage purposes, the tools can adapt the user interface to enable modelling at different coercion degrees.

Tree-based Authoring Tool

The user interface of the tree-based authoring tool is shown in Figure 2. The window of the tool consists of a tool bar and two panels. The left panel is used to define the CSCL script structure and the right panel is used to create detailed designs. In the script structure panel, each CSCL script is shown as a tree in which compound activities are represented as intermediate nodes and atomic/routing activities are represented as leaves. Like IMS-LD, there is no transition between subactivities of a selection activity. However, all transitions between subactivities nested in a networked activity have to be explicitly represented. The sub-flow of a sequence activity can be represented as a sequence of activities and the order implies the transitions. Such a design is based on a fact that the main structural relations of collaborative learning scripts are sequential.

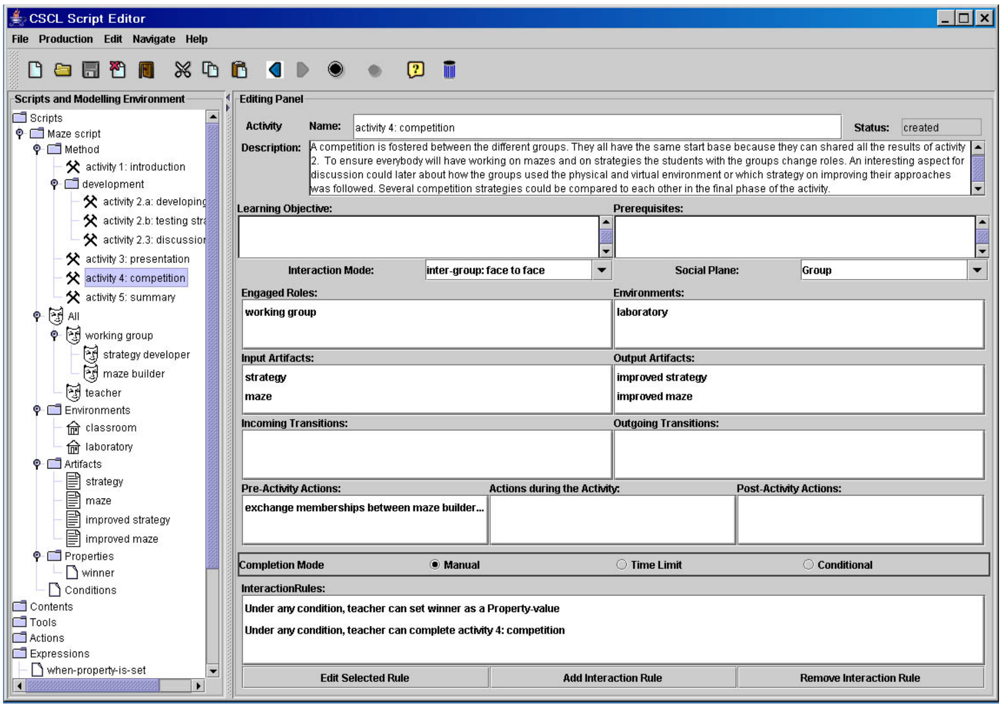

Figure 2: The user interface of the tree-based authoring tool

Figure 2 shows an example definition of the maze script. The root process structure of a script is called a method. The method of the maze script contains five activities represented in a sequence. Among these the second one is a compound activity of a type “concurrent” which contains three concurrently executable subactivities. The following sub-trees are other CSCL script components including roles, environments, artefacts, properties, and conditions. Other trees below are reusable components such as contents, tools, actions, and expressions. A user can create or load a CSCL script and then create elements such as activities, transitions, roles, environments, artefacts, and so on that make up a script. If selecting an element, the user can see and edit the detailed specification of the element. Figure 2 illustrates the definition of activity 4. The tool allows for defining the relations between elements by using drag & drop operations. For example, if assigning a role named “working group” to the activity named “activity 4”, the user can drag the tree-node representing the role from the script tree and drop it in the list of “Engaged Roles” of the activity 4.

Diagram-based Authoring Tool

The diagram-based tool is based on state chart diagrams. It supports the definition of complex control flows on arbitrary levels. Each state node corresponds to an activity and each arrow represents a transition. The nested sub-flow of an activity can be specified by drawing a new state chart in a new workspace that pops up when double clicking the activity node. The designer can create and remove elements (like a role, a tool or an artefact) by using drag & drop operations. Detailed specification of each element can be defined within a popped-up dialog window for each kind of elements.

upper level view fragment Detailed view on subactivity flow of an upper level activity

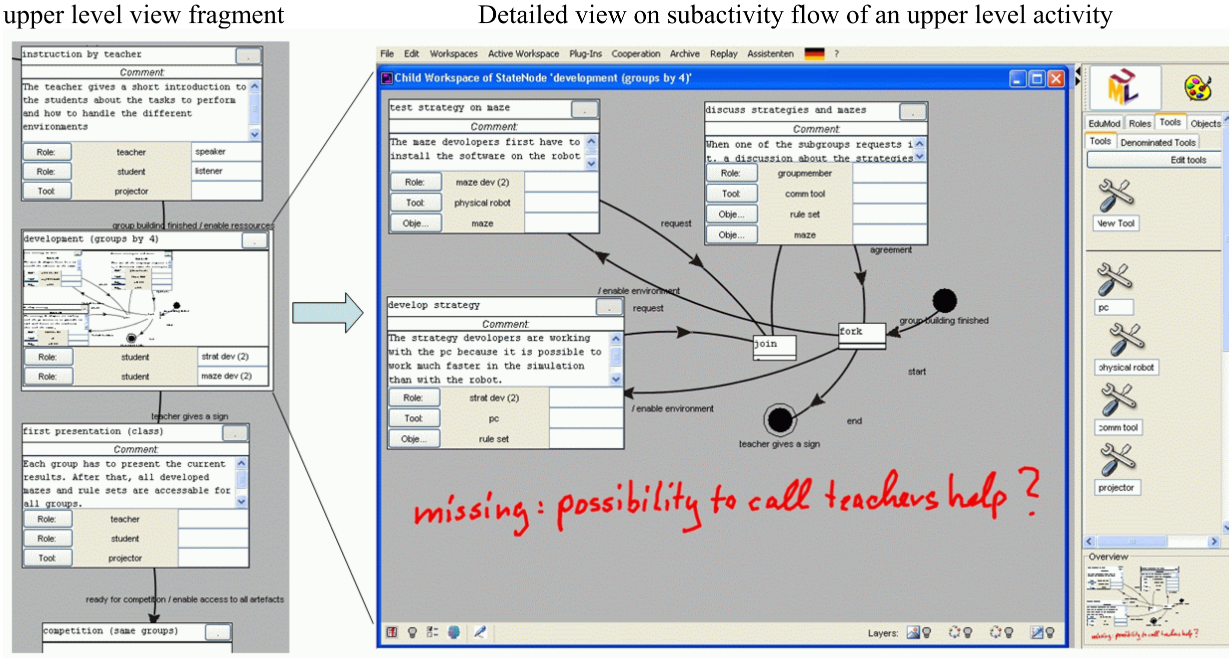

Figure 3: The user interface of the diagram-based authoring tool

Figure 3 shows two screenshots of the maze script representation (control flow) in the diagram based modelling tool. On the left, it shows a fragment of the upper level control flow of activities. Here this is a simple sequence. The designer can decide for each activity node to show either a pedagogical comment (like e.g. the upper activity) or a sketch of its sub activities (like the activity node in the middle). She can also assign and denominate roles, tools, etc. to an activity which can be used when defining sub activity flow. This can be done by double clicking on an activity and can be repeated to any level. A new workspace is opened like it is shown on the right part of Figure 3 which is a screenshot of the whole tool. On the right border you can see the drag and drop area of the tool. This tool is realised as a plugin for our Cool Modes modelling environment (Pinkwart, 2003).

POTENTIAL USES AND SYSTEM SUPPORT OF CSCL SCRIPTS

The specification of learning processes using a modelling language may have a broad variety of purposes on the designer’s side. Some educational designers use it as a note taking tool for for lesson planning, some for discussion with colleagues and some expect these models to be executed automatically within a customised computer-based learning environment. With this in mind, we want to explore and elaborate the different motivations designers might have and potential functionalities a run-time system may provide from a given learning process specification. One of the dimensions for our exploration is the degree of “informedness” on the part of the computer system necessary to provide the desired functionality: we see a continuum from complete uninformedness of the system and exclusive interpretation on the user’s side up to quite high requirements of interpreting/understanding the learning processes within the system. We will begin our discussion on the end of the “uninformed system”.

System as Editor/Viewer:
Basically, designers of learning processes can use their models as blueprints for their teaching or experimental design. When the model is also used to communicate the process to other actors (other designers, experimentors, students) the modelling language has the function of a communication language, the learning process models have the function of a shared artefact in the communication. A well-known example for this type of usage of modelling languages is the Unified Modelling Language (UML) as a lingua franca for software design and specification. We think that a visual modelling language for learning processes with an elaborated conceptual model could be of similar importance to learning designers as UML is for software engineers. This type of usage does not require any interpretation on the part of the system, but nevertheless the system can provide the syntactic elements of the modelling language in form of a model editor with persistent storage and thus re-use and exchange of models. When visualising the learning flow to the learners directly, this artefact can be seen as a navigation structure and therefore a means of self-reflection on the learner’s side (“What should I do here?”), even without any monitoring capabilities of the system (we will go into detail on that at the end of the section).

Syntactical mapping to a visual/conceptual representation:
If the system has an explicit representation of the syntactical elements not only on the user interface level but also in the internal data model, the system can additionally provide a mapping from syntactically defined learning processes to a user-understandable visual representation. This enables interoperability in terms of the exchange of learning process specifications that have been produced with different tools given a compatible syntax (either the same or transformable via a syntactic mapping). With a well-defined syntax available in the system, tools can support the learning designers in producing syntactically correct models (with techniques like highlighting of syntax errors) an important prerequisite for further processing of the model.

Presentation of models in multiple perspectives:
Rich, expressive modelling techniques usually bring along the problem that models get excessively complex and hard to overlook. Therefore either reduction of the complexity (by applying projections of specific elements or filtering techniques) or the separation into different perspectives (like the different diagram types in UML) is a typical way to cope with the complexity. For learning processes typically the following aspects are relevant and thus candidates for special perspectives:

- *Procedural/Temporal Perspective*: naturally the sequence and timing, i.e. the processual aspects of the whole learning process should be represented explicitly
- *Artefacts Perspective*: artefacts given as resources, used as temporary results and the final outcome of learning activities constitute an important aspect of learning processes. Especially the change of artefacts over time (version history) is information to consider by all participants of a learning process.
- *Roles Perspective*: for organisation of specific tasks in group processes the various roles needed for the tasks are an essential information both for designer and for learners. With a suitable perspective the designer keeps the overview about the work organisation and the learners can reduce their uncertainty (Mäkitalo et al. 2004) about their role, i.e. the function that is expected from them, in the learning process.
- *Individual/Group Perspective*: to get an impression of the workload of one specific member or one subgroup within a group process a perspective stressing these individual aspects is a valuable information for the designer to keep balance between the participants of the process. For the participants this perspective can give orientation about their progress and a ‘ToDo list’ as a scaffold for their activities.

The multi-perspective representation of the learning design requires that the system explicitly has information which elements belong to which perspective(s), especially when relations between perspectives should be highlighted. Therefore an additional level of information, i.e. the assignment of syntactical elements to the different perspectives has to be present to support the users properly.

Up to this point, we can call the computer support described so far as a rather syntactic, without considering higher-level properties of the learning flow, such as executabilty or structural aspects on semantical level. In the following paragraphs we will shed some light on this kind of advanced support mechanisms:

Model-based prediction
An explicit representation of the model can be used to give advise or comments to the designer of the learning process with respect to her design: E.g., dependencies or constraints between elements can be highlighted, such as necessity of sequential phases or synchronising the flow after a split into cooperative subprocesses. If the

designer specified temporal constraints (minimum or maximum time) for elements of the process, techniques from operations research, such as optimisation in network flows or critical path analysis can be applied. With this kind of support the designer can find weak spots in the design, such as an inappropriately long waiting time for the participants in one subprocess when synchronising with another subgroup whose activties take much more time. Scheduling algorithms may propose a different sequencing for the revision of the design then.

Simulation

A simulated execution of the specified learning process can give the designer a more profound feedback on "what works and what does not?". Imagine the benefit of doing a "simulation run" with information about sequence, time requirements, produced artefacts before applying the whole design to a real experiment. The plausibility of the design can be checked much easier than just based on the static structure of the model. This clearly requires an "operational semantics" of the learning process modelling language to provide execution runs of the specified learning process (e.g. operationalising which activity follows which others and how to complete/end activities). It should be possible to explore such a simulation interactively and stepwise, for more thorough testing of the processes' feasibility a "batch" mode or even exhaustive simulation with different inputs may be desirable. Deadlocks (e.g. when subgroups are waiting for each other's input) in the process specification can be detected before making the bitter experience in practical use. The degree of detail for simulation will also vary here, from rather general level, such as interactively giving a specific ordering of activities, to full simulation of the users' interfaces which would be equivalent to a full-fledged execution engine for the process and thus to the expected functionality of a "player".

Static configuration of the learning environment

The first, weak approach to operationalising the learning process for the target user "at run time" is the configuration of the learning environment with available tools, resources, communication structure and so on. If this configuration is done once without dynamic addition and removal of elements we call this static configuration. This gives the target users the full potential of available elements, but without the constraints and restrictions that may have already been specified by the designer. "Compiling and instantiating" such an environment from the specification should be the minimal functionality of a system meant for "playing" the learning design.

Monitoring of the learning flow

Enriched by computable conditions how and when to end activities, how to measure the progress state of artefacts etc. the operational character of the computer support can be substantially enhanced. Given this additional information, monitoring of the learning flow and management of the constraints specified by the designer is possible. The computer support takes the form of a fully operational execution of the process. This level has not yet been achieved for IMS/LD players, because Level A compliance is not sufficient to handle complex conditions that influence the flow at runtime. Monitoring functionality could be used twofold: On the one hand the information can be used internally to adapt the process according to the exact specification, on the other hand the monitored information can be visualised to participants of the learning process and give them information on what they have done and produced. This additional feedback can be used to promote reflection about the process or the participants' own behaviour, such stimulating meta-cognitive activities. Yet, just thinking of execution of a predefined learning process is not enough: Modern interactive learning environments allow the learners to structure their learning process very flexibly. Here, the recognition problem is known to be very hard. On the other hand, the strive for learning monitors should not induce additional restrictions on the learner.

Model-based scaffolding

At the "informed end" of the spectrum of computer support we see the potential use of the system for scaffolding the learning process, especially when the "typical path" through the process was left by the participants. An enriched specification can give advise to the learners on "what and when to do, how they can play their assigned role best" and so on. Depending on the strictness of the scaffolding the system's behaviour can vary between an unrestraining advisor and an interventing tutor. For this functionality, existing approaches both from the area of "intelligent tutoring systems" and from "interaction scripts" as discussed in cognitive and social psychology can be considered. The information needed for this functionality has aspects of operational character (what to do in special circumstances) but also of the "rationale" the designer had in mind with the specified activities (why is that activity important and how to implement it).

CONCLUSIONS AND FUTURE WORK

In this paper we have stated five major limitations of IMS LD when formalising CSCL scripts. Based on this, we have suggested a scripting language for CSCL. The identified problems of IMS LD are solved in the language respectively by: 1) explicitly introducing the group entity to facilitate modelling organisational role and behaviour role; 2) explicitly introducing the artefact entity to enable designers to model artefact and information flow easily and intuitively; 3) extending process element operations and providing declaration mechanisms to capture dynamic features of collaborative learning processes; 4) exploiting WfMS routing technologies to enable specifying complicated control flow; and 5) giving up the metaphor of theatrical play and the role-part and using activity-centered definition method to model varied forms of social interaction. Furthermore, we systematically discussed the potential usages of CSCL scripts and possibilities of system support.

Based on the CSCL scripting language, we developed two script authoring tools using different representation perspectives: the tree-based view and the diagram-based view. Currently we focused on testing the modelling capacity of the proposed CSCL scripting language, in order to improve the capacity of our language and the feasibility of the tools. Real experiments will be conducted in the near future. Later on, we will develop an integrated environment to provide a full spectrum of system support from modelling, analysing, simulating, monitoring, to scaffolding.

ACKNOWLEDGEMENTS

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An Experimental Study on Collaborative Scientific Activities with an Actual/Imaginary Partner

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Abstract. In this study, we experimentally investigate collaborative scientific activities that are undertaken through a virtual space such as the Internet. In such cases, a partner has two aspects: an *imaginary partner* with whom the problem solver seems to work together, and an *actual partner* with whom he/she actually works. We design an experimental environment in which we can control the two factors independently. The experimental result shows: (1) a bias appearing in human behavior, such as the positive test bias in hypothesis testing, was not influenced by the change of an *actual partner*; however (2) the degree of using information given by a partner, such as reference to a partner's hypothesis, varied considerably with the change of an *actual partner*. Neither phenomenon above depended on the type of *imaginary partner*.

Keywords: Scientific discovery, Collaborative problem solving, Internet, Hypothesis testing

INTRODUCTION

In this study, we experimentally investigate collaborative scientific activities that are undertaken through a virtual space such as the Internet. In particular, we focus on hypothesis formation and verification stages, which are the most typical processes in scientific activities. In cognitive science, there is an enormous number of studies on scientific discovery by problem solvers working solo or in pairs (e.g., Gorman, 1992; Klahr, 2000). On the other hand, there are only a few studies on collaborative scientific discovery in non-face-to-face situations, which are engaged via virtual space.

A partner (collaborator) is an important factor in determining collaborative scientific activities. In the case of collaboration via virtual space, a partner has two aspects: an *imaginary partner* with whom the problem solver seems to work together, and an *actual partner* with whom he/she actually works; additionally, the situation may arise where the two aspects of a partner are not identical.

Recently, we have begun to experience not only HHI (Human-Human Interaction) but also HAI (Human-Agent Interaction), and the interest in such interaction is increasing. Reeves & Nass (1996) proposed the Media Equation framework in which they concluded that human beings relate to computer or television programs in the same way they relate to other human beings. Following after their framework, many studies investigated how computational agents act effectively like human instructors (e.g., Baylor, 2000; Moreno, et al., 2001; Morishita et al., 2004). In such interaction, there may be a case where people believe they are collaborating with humans (*imaginary partners*) but are actually collaborating with computational agents (*actual partners*). The reverse relation is also possible. Additionally, we can intentionally set up the above situation such as designing an environment for CSCL. We believe that it is important to study this type of interaction not only for responding to pragmatic requirements in designing CSCL and CSCW environments, but also for understanding fundamental features on human collaborative problem solving.

In this study, we design an experimental environment where we can control experimental factors on both *imaginary* and *actual* partners independently, and we investigate the above issues, focusing on hypothesis formation and testing in scientific activities. Concretely, in each of the various collaboration situations, which were constructed with combinations of *imaginary* and *actual* partners, we attempt to understand (1) through hypothesis verification how people's hypothesis-testing strategy is influenced by a partner's strategies, and (2) via hypothesis formation how people change to refer to another hypothesis given by a partner.

TASK AND BACKGROUND

2-4-6 task

In this study, we use Wason's 2-4-6 task as an experimental task (Wason, 1960). The reason for using this task is that it has been used as a standard experimental task in studies on human discovery, and that the nature of the task is well understood (Newstead & Evans, 1995). The standard procedure of the 2-4-6 task is as follows (see Table 1). All subjects are required to find a rule of a relationship among three numerals. In Table 1, the target rule is “three evens.” In the most popular situation, a set of three numerals, "2, 4, 6," is presented to subjects at the initial stage. The subjects form a “Hypothesis” about the regularity of the numerals based on the presented set. The subjects then produce a new set of three numerals and present it to the experimenter. This set is called an instance. The experimenter gives a Yes as “Feedback” to the subjects if the set produced by the subjects is an instance of the target rule, or a No as feedback if it is not an “Instance” of the target rule. The subjects continuously carry out experiments, receive feedback from each experiment, and search to find the target.

Table 1 Example process of solving the 2-4-6 task.

Hypothesis	Instance	Feedback	States
	2, 4, 6	Yes	
Three continuous evens	6, 8, 10	Yes	Positive hits
Three continuous evens	0, 10, 30	Yes	Negative hits
The interval is the same	0, 10, -5	No	False negatives
The interval is the same	0, 10, 50	Yes	Negative hits
Ascending numbers	1, 5, 100	No	False positives
…			

Important concepts

First, we briefly explain important concepts regarding the two key factors, i.e., the nature of the targets that the subjects try to find and the hypothesis-testing employed by the subjects.

- The nature of targets: We categorize the targets from the viewpoint of their generality. We define targets as broad targets if the proportion of their members (positive instances) to all instances (all sets of three numerals) in the search space is large. On the other hand, we define targets as narrow targets if the same proportion is small. An example of the former type of target is "the product of three numerals is even" (where the proportion of target instances to all possible instances is 7/8), and an example of the latter type is "three evens" (where the proportion is 1/8).
- Hypothesis testing: There are two types of hypothesis testing: a positive test and a negative test. The positive test (P-test) is conducted in an instance where the subject expects there to be a target. That is, the P-test is a hypothesis test using a positive instance for a hypothesis. The negative test (N-test) is, in contrast, a hypothesis test using a negative instance for a hypothesis. For example, if a hypothesis were about "ascending numbers," the P-test would use a sequence like "1, 3, 9"; the N-test would use a sequence like "1, 5, 2."

Klayman & Ha (1987) summarized states in which a subject's hypothesis is falsified (see the “States” column in Table 1). Let us consider a case where the target is "three evens" and the subject's hypothesis is "ascending numbers." When the subject conducts a P-test using the instance "1, 3, 5" and then receives a No feedback, his/her hypothesis is disconfirmed (*false positives*). Another state of conclusive falsification is caused by the combination of a N-test and a Yes feedback, using the instance "8, 6, 2" (*negative hits*). On the other hand, states of ambiguous verification are obtained from the combination of a P-test and a Yes feedback, using "4, 6, 8" (*positive hits*), or the combination of a N-test and a No feedback, using "5, 3, 1" (*false negatives*).

EXPERIMENTAL DESIGN

Design

Pairs of subjects separated into different rooms participated in the experiment. Each subject sat in front of a computer terminal through which he/she solved the 2-4-6 task collaboratively with a partner. Each subject could refer to the partner's hypothesis. Until the end of an experiment they were permitted to generate twenty instances to identify the target rule. That is, they observed a total of twenty-one instances including the first one, "2, 4, 6", indicated by the system. Each of the two subjects alternately generated instances, thus each generated ten of the twenty instances. Each subject could refer to instances generated by the partner. Figure 1 shows an example screenshot of a terminal in the process of the experiment.

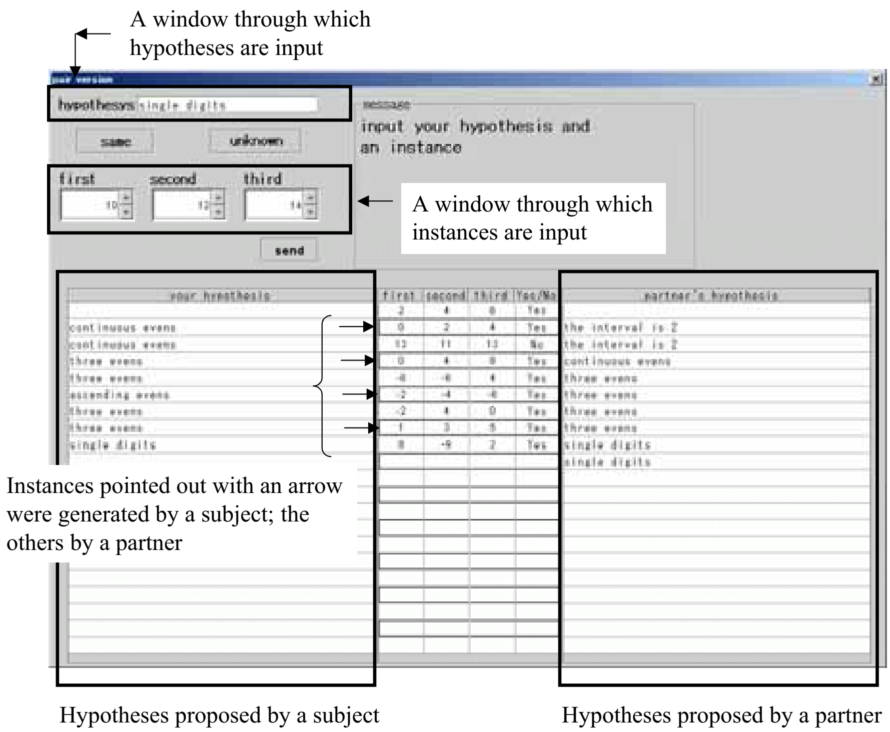

Figure 1 An example screenshot of the experimental environment.

Each subject found two kinds of target rule. One target was "the product is 48," while the other was "three different numbers." The former is an example of a narrow target and the latter is an example of a broad target. The order of the targets used in the experiment was counter-balanced.

Experimental factors

A three (*actual partners*) x two (*imaginary partners* brought about by the experimenter's instruction) between-subjects design experiment was conducted. Table 2 shows the numbers of subjects assigned to each condition. A total of ninety-six undergraduates participated in the experiment.

Table 2 Numbers of subjects participating in the experiment.

		Imaginary partners (Instruction)	
		Human	Agent
Actual partners	Human	16	16
	Positive-test Agent	15	17
	Negative-test Agent	16	16

The first factor was related to an *actual partner*, where three cases were set up: (1) a case of collaboration with a human subject (w/ Human), and (2) a case of collaboration with a computer agent. The latter case was subdivided into two sub cases: (2a) collaboration with an agent who uses the positive test strategy in hypothesis testing (w/ P-test Agent), and (2b) collaboration with an agent who uses the negative test strategy (w/ N-test Agent). The reason for adopting these strategies in this study is that this issue has been recognized as one of the most important topics in the human discovery process (Klayman & Ha, 1987; Laughlin, et al., 1987).

The second factor was related to an *imaginary partner* brought about by the experimenter's instruction. Two cases were set up: (1) a case where subjects were instructed to collaborate with a program installed on a computer they were manipulating, and (2) a case where they were to collaborate with a human subject in a different room, with whom they could communicate via the Internet.

Method of controlling the factors

The first factor (an *actual partner*) was manipulated as follows. When collaborating with a human subject, each terminal was connected to the Internet via wireless LAN, and each subject solved the problem with a partner in a different room via the Internet. On the other hand, in the case of collaborating with a computer agent, each terminal operated independently from the others and each subject solved the task with an agent established on a computer. The agent, i.e., the computational problem solver, was developed in the author's preceding study (Miwa, 2004).

The second factor (an *imaginary partner*) was controlled according to the experimenter's instruction. When leading the subjects into a situation of collaboration with an imaginary human subject, a terminal was connected to an Internet socket with a dummy cable, and the subjects were guided to imagine interaction with a partner in a different room. On the other hand, when collaborating with an imaginary computer agent, the dummy cable was removed; the subjects imagined that their terminal worked independently because the connection with the Internet was achieved via wireless LAN.

RESULTS

Subjective estimation of the goodness of collaboration

After the main experimental session, the subjects were required to estimate the degree of goodness of collaboration with a partner on a scale of 1 to 5. Figure 2 shows the average of the estimated degree in each experimental condition. A 2 (*imaginary partners*) x 3 (*actual partners*) ANOVA revealed that the main effect of an *actual partner* reached significance ($F(2, 90)=10.79$, $p < 0.01$); a LSD analysis showed that the degree with Human was higher than that with the P-test Agent and the degree with the P-test Agent was higher than that with the N-test Agent ($MSe=0.8874$, $p < 0.05$). On the other hand, the main effect of an *imaginary partner* was only marginally significant ($F(1, 90)=3.29$, $p < 0.1$). The interaction of the two factors was not significant ($F < 1$).

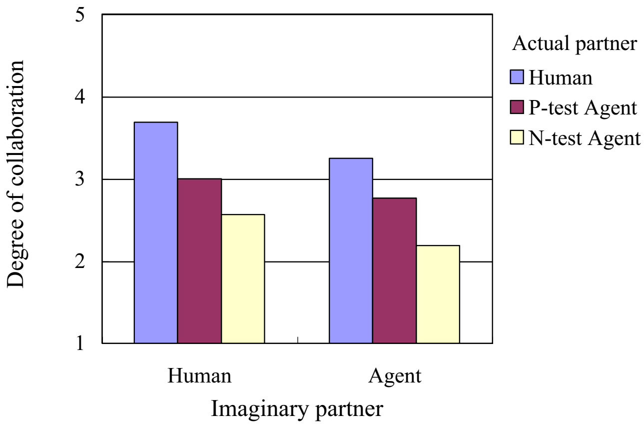

Figure 2 Degree of subjective estimation on goodness of collaboration.

Hypothesis testing

Here we discuss how subjects' hypothesis testing strategies are influenced by a change of partner. Cognitive psychological studies on human hypothesis testing have indicated that humans have a strong bias for conducting positive tests rather than negative tests (Mahoney & DeMonbruen, 1997; Mynatt, et al., 1977). This bias is called the positive test bias. To what degree does this bias change in each type of collaboration dealt with in this study?

Figure 3 shows the ratio of instances being positive ones for subjects' hypotheses, separated into instances generated by subjects themselves and instances by their partners. In other words, Figs. 3(a) and (c) show the ratio of conducting the positive test in the subjects' hypothesis testing, while Figs. 3(b) and (d) show the ratio of their partners' instances fulfilling the positive test for the subjects' hypothesis.

Figures 3(a) and (c) show that the ratio of the positive test in the subjects' hypothesis testing was invariable regardless of the change of partners. A 2 (*imaginary partners*) x 3 (*actual partners*) ANOVA did not reveal any significance (in finding the broad target the main effect of an *imaginary partner*: $F < 1$; the main effect of an *actual partner*: $F(2, 90)=1.59$, $p > 0.1$; the interaction: $F < 1$, in finding the narrow target the main effect of an *imaginary partner*: $F < 1$; the main effect of an *actual partner*: $F < 1$; the interaction: $F < 1$).

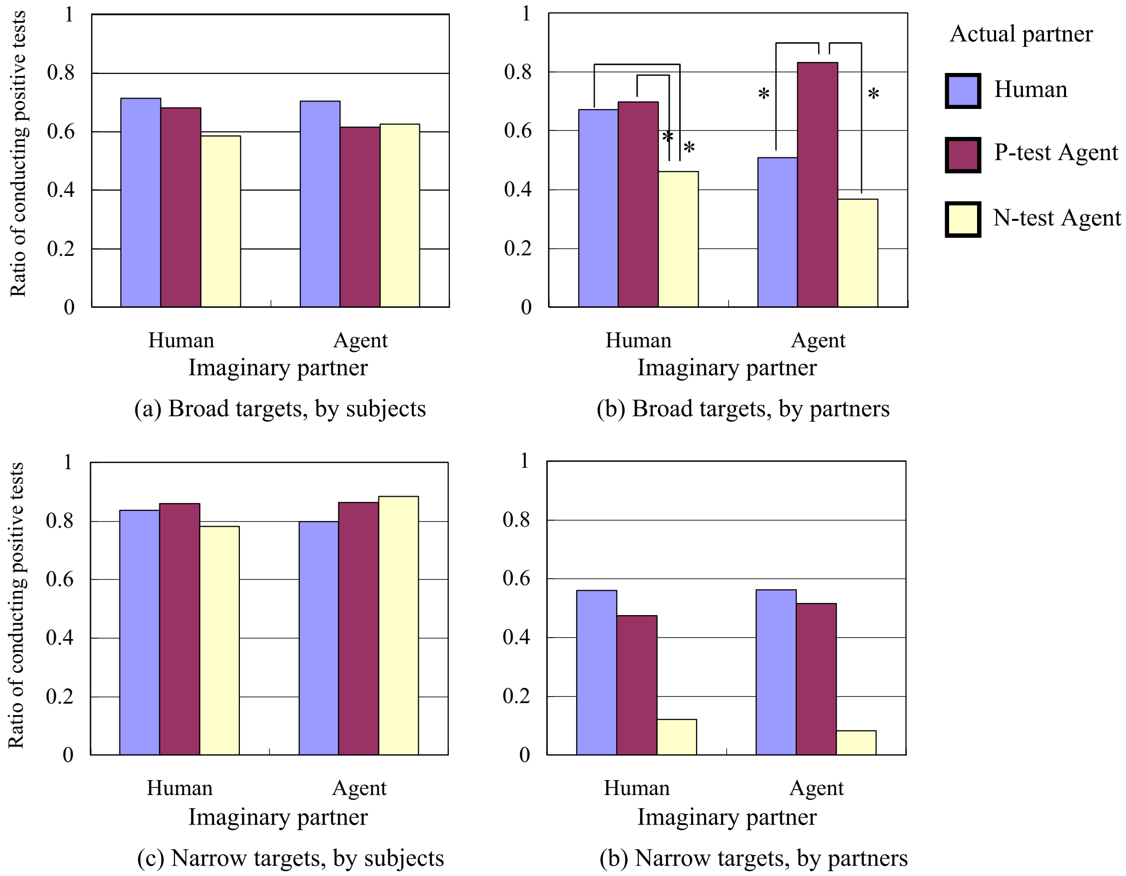

Figure 3 Ratio of conducting positive tests.

This point becomes more interesting when we compare collaboration with the P-test Agent and collaboration with the N-test Agent, where the partner's hypothesis testing strategy was controlled. Figures 3(b) and (d) show that in collaboration with the P-test Agent, the ratio of the partner's instances fulfilling the positive test for the subjects' hypothesis was higher than in collaboration with the N-test Agent. A 2 (*imaginary partners*) x 3 (*actual partners*) ANOVA revealed that the interaction between the two factors was significant in Fig. 3(b) ($F(2, 90) = 4.21$, $p < 0.05$) and the significant difference by a LDS analysis is indicated by a "*" in the figure ($MSe=0.0455$, $p < 0.05$). The same ANOVA reveals that the main effect of an *actual partner* was significant in Fig. 3(d) ($F(2, 90) = 35.87$, $p < 0.01$), and a LDS analysis indicated that the ratios in the Human and P-test Agent conditions were higher than that in the N-test Agent condition ($MSe=0.0537$, $p < 0.05$). Neither the main effect of an *imaginary partner* nor the interaction was significant ($F < 1$, $F < 1$, respectively). This means that even though the quality of information of the instances given by a partner varied depending on the change of an *actual partner's* hypothesis testing strategy, this did not influence the subjects' positive test bias. Moreover, this consistency did not depend on the experimenter's instruction as to whether the subjects collaborated with a human subject or with a computer agent (i.e., the change of an *imaginary partner*).

Hypothesis formation

Laughlin & Futoran (1985) indicated that in group activities an individual accepts other group members' hypothesis as his/her own hypothesis while estimating the validity of the others' hypotheses accurately, and this brings about the superiority of group activities to individual activities. Next, we discuss how subjects' reference to a partner's hypothesis in their hypothesis formation is influenced by the change of a partner.

Figure 4 shows the ratio of cases in which subjects proposed an identical hypothesis to the partner's when they revised their own hypothesis. A 2 (*imaginary partners*) x 3 (*actual partners*) ANOVA revealed that the main effect of an *actual partner* was significant in finding the broad target (F(2, 90) = 7.71, $p < 0.01$), and a LSD test showed that the ratios in the Human and P-test Agent conditions were higher than that in the N-test Agent condition (MSe=0.0407, $p < 0.05$). Neither the main effect of an *imaginary partner* nor the interaction was significant ($F < 1$, $F < 1$, respectively). In finding the narrow target, no statistically significant effect was found (the main effect of an *imaginary partner*: F(1, 90) = 1.50, $p > 0.1$; the main effect of an *actual partner*: $F < 1$; the interaction: $F < 1$). This means that in such cases the subjects' tendency to adjust their hypothesis to the partner's hypothesis became stronger. This tendency did not depend on the experimenter's instruction as to whether the subjects collaborate with a human subject or with a computer agent (an *imaginary partner*).

In cases of collaboration with a computer agent, the algorithm in the agent's hypothesis formation was consistent; therefore the subjects were presented with similar hypotheses under the P-test Agent and N-test Agent experimental conditions. However, it is interesting that the subjects tended to adjust their hypothesis to the partner's more remarkably when collaborating only with the P-test Agent. As Fig. 2 showed, the subjects felt that collaboration with the P-test Agent was more familiar than collaboration with the N-test Agent; this tendency may bring about the tendency of strong adjustment to hypotheses given by the positive test agent.

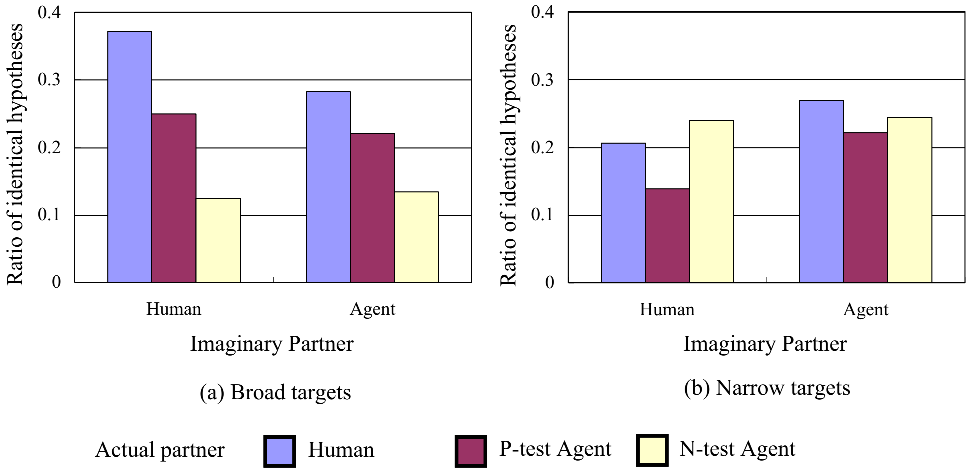

Figure 4 Ratio of adjustment of subjects' hypothesis to the partner's.

CONCLUSIONS

The experimental result shows:
(1) a bias appearing in human behavior, such as the positive test bias in hypothesis testing, was not influenced by the change of an *actual partner*;
(2) the degree of using information given by a partner such as reference to a partner's hypothesis varied considerably with the change of an *actual partner*.

Neither phenomenon above depended on type of *imaginary partner* that was provided by the experimenter.

In finding the narrow target, there was no tendency of subjects adjusting their hypothesis to the P-test Agent's hypothesis (see Fig. 4(b)), whereas there was a tendency found in finding the broad target (see Fig. 4(a)). Why did this difference emerge?

In finding the broad target, the possibility of the agent receiving a Yes as feedback in the experiment was much higher than that in finding the narrow target (see the definition of types of target). Actually the former possibility was 0.75, whereas the latter was 0.21. Therefore, in finding the narrow target, the P-test Agent faced many *false positives* by receiving a No feedback, which repeatedly rejected the agent's hypothesis. On the other hand, in finding the broad target, the P-test Agent faced many *positive hits* by receiving a Yes feedback, confirming its hypothesis many times (Klayman & Ha, 1987; Miwa, 2004). From the viewpoint of the subjects who observed the agent's activity, this means that in finding the broad target, the P-test Agent seems to propose a reliable hypothesis whereas in finding the narrow target, it usually proposed a dubious one. This difference brought about the result that only in finding the broad target did the subjects tend to adjust their hypothesis to the agent's hypothesis.

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Promotion of Self-Assessment for Learners in Online Discussion Using the Visualization Software

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Abstract. This study describes a method of self-assessment for learners in a collaborative discussion. The authors propose a method of self-assessment in an online discussion and examine its effectiveness through the development and evaluation of a software program to visualize the discussion on a Bulletin Board System. The software, referred to as "i-Bee" (Bulletin board Enrollee Envisioner), can visually display the co-occurrence relation between keywords and learners. Thus, the i-Bee can display the content-wise contribution made by each learner to the discussion. In addition, the i-Bee can display the recent level of participation of each learner and the frequency of each keyword used by the learners. The i-Bee enables students to assess and reflect over their discussion, to understand the condition, and to reorganize their commitment in a discussion reflecting their learning activity.

Keywords: Visualization, Self-assessment, Reflection, Online Discussion

INTRODUCTION

The study of Computer Supported Collaborative Learning (CSCL) is a challenge with regard to producing an environment conducive to mutual learning among learners using computers. Recent researches in e-learning have highlighted the significance of building an online learning community, which plays a role in the sustenance of a fruitful online learning experience (Palloff and Pratt, 1999). The significance of promoting communication among learners via the Computer-mediated communication (CMC) is rapidly increasing at present.

However, there are some difficulties faced by learners in mutually recognizing the status of a learning activity in the CSCL environment, which constitutes the most important research issue (Gutwin et al., 1995; Kato et al., 2004). Japanese communication researchers, Kimura and Tsuzuki (1998), pointed out that group communication in the CMC tends to be disorganized and to lack cohesion due to decreased interpersonal pressure, given the nature of the CMC. Briefly, learners are sometimes confused about what they should and should not discuss. This raises the question of how CSCL environments assist learners in recognizing their commitment and reorganizing their discussion in a content-wise manner?—if not, it may lead to a failure in the organization of a fruitful discussion for learning.

In order to address this issue, the authors propose a method to self-assess the online discussions in electronic forums or Bulletin Board System (BBS). Self-assessment is very effective for learners seeking to improve their knowledge and learning strategy (Shaklee et al., 1997), particularly in a collaborative learning setting. Learners are required to monitor the actual condition of their discussion, the learning process, and interpersonal relations in order to improve their learning community, and to plan the course of their education, which will enable them to make learning a significant experience.

Messages exchanged in the electronic forums are useful in the assessment of collaborative learning given the fact that they are visualized resources of interaction among learners in a collaborative learning setting. In other words, the messages exchanged in a discussion are reflective of the learner's ability in the context of the activity (*in situ*) (Pea, 1993; Palincsar, 1998)—according to the social constructivism perspective, the learner's ability in a collaborative learning setting emerges socially; therefore, the ability should be assessed on the basis of a visualized interaction among learners and the circumstances including artifacts and social factors. However, a manual assessment of these messages by the learners is not practical given the tremendous effort that is required of them.

In this study, the proposed method of content-wise visualization of the communication produces a mapping of coordinates, which indicates how strongly each learner relates to each keyword in his/her messages. Mapping reveals the whole structure of communication in the learning community—the manner in which each learner participates in the communication and the organization of group communication.

In order to examine the validity and usefulness of the proposed method, the authors developed a software referred to as "i-Bee," (Bulletin board Enrollee Envisioner), which can visualize the relationship between learners and keywords in online messages in real time. This software also provides snapshots of past discussions and animations, which show the trajectory of change from a given period. Thus, the i-Bee aims to encourage learners to perceive their discussion as a whole and to encourage them to assess their discussion.

The purpose of this study is to examine the effectiveness of self-assessment of online discussions through the development and evaluation of the i-Bee based on the proposed method. With regard to learners' self-assessment, this study primarily focuses on and discusses the experience of learners to recognize and improve a discussion using the i-Bee.

VISUALIZING ONLINE CONVERSATION

Several recent studies in CSCL have focused on visualization of learner activities in CSCL in order to create awareness among learners. For example, Nakahara et al. (in printing) developed a software, which visualized the status of interaction and activeness of electronic forums on a mobile phone screen, in order to promote participation awareness and encourage learners to participate in the discussion at any time. Other researchers have attempted to visualize social networks in the community (e.g. Martínez et al., 2003) by confirming the status of communities in CSCL. However, to date, very few precedent researches have focused on the visualization of contents of the discussion among learners. Puntambekar and Luckin (2003) have indicated that it must be worthwhile to allow learners to view the contents of the discussion and learn through reflecting over the process.

In this study, the authors propose a visualization method using a text-mining technique to assess conversation among learners on the BBS.

Application of Text-mining Technique

Researches in the field of text-mining have progressed in recent years. Numerous methods have been developed for extracting applicable keywords from the text data. Additionally, multivariate analyses such as the multivariable dimension scale (MDS) and Correspondence Analysis (CA) are generally used to visualize the relationship of individual keywords to the whole (Greenacre, 1984).

CA is a graphically descriptive method that facilitates an intuitive understanding of this relationship by presenting two or more discrete variables in a complex data matrix. For instance, when the matrix is based on the frequency of each keyword written for each person or group, frequently co-occurring variables are placed in close proximity to each other. It is considered to be suitable for learners to recognize the content-wise contribution made by each learner to the discussion as clusters (of keywords and persons) that are related elements in the text data (Li and Yamanishi, 1999). In addition, rather than Latent Semantic Analysis (Landauer, et al., 2004) which is suited for analyzing large amounts of data, CA is a more appropriate method to analyze small statistical data like messages on the BBS in a small group activity, since CA is independent from statistical assumptions.

Visualizing Discussion Using CA

In the method proposed in this study, if n learners discuss a relevant number of m keywords, which totals up to $n \times m$ for a cross-tab of $\mathbf{N}$, then CA yields a mapping of a row vector $\mathbf{F}$ and a column vector $\mathbf{G}$. In other words, the generalized singular value decomposition of the matrix $\mathbf{P}$, which is the relative frequency matrix of $\mathbf{N}$,

$$\mathbf{P} = \mathbf{A}\,\mathbf{D}_{\mu}\,\mathbf{B}^{T}$$

yields a left generalized singular vector **A** and a right generalized singular vector **B**. The use of these two vectors,

$$\mathbf{F} = \mathbf{D}_{R}^{-1}\,\mathbf{A}\,\mathbf{D}_{\mu}$$

and

$$\mathbf{G} = \mathbf{D}_{C}^{-1}\,\mathbf{B}\,\mathbf{D}_{\mu},$$

results in the standardized principal coordinates **F**, **G**, which construct a mapping (Greenacre, 1984).

In this mapping, $\mathbf{D}_{\mu}$ is the diagonal matrix leading to the generalized singular value diagonal vector, $\mathbf{D}_{R}$ is the diagonal matrix that makes matrix **P** the diagonal vector, and $\mathbf{D}_{C}$ is the diagonal matrix of the sum of the columns of matrix **P**. Additionally, **F** and **G** correspond with the coordinates of learners and keywords, respectively.

The Significance of Mapping Generated by the Analysis

Generally, when a CA is conducted using the relative frequency matrix **P**, **F** and **G** are distributed in proximity to each other if a coordinate of **F** and that of **G** have a strong co-occurrence relation. In contrast, if a coordinate of **F** and that of **G** do not have a co-occurrence relation, they are distributed far away from each other. In addition, a relatively high value in the matrix **N** represents a coordinate located closer to the original point and a relatively low value represents a coordinate located far from the original point.

Thus, it is believed that (1) the distribution of coordinates indicates the co-occurrence relation between each learner and each keyword in his/her messages and (2) the total data of (1) represents the topics in the discussions. Hence, CA can display the status of an overall discussion in the BBS as well as each learner's involvement in that discussion. Although other aspects of discussion, such as meaning and context, does not taken into consideration in the analysis, CA is simple and applicable to incomplete and fragmental sentences as seen in BBS messages.

The authors have already conducted a pilot study to examine the appropriateness of CA in order to visualize the discussion and to examine the effectiveness of mapping for the learner's self-assessment. The result is indicative of the possibility of learners focusing more on certain topics of participation, planning their participation in topics of lesser interest, and following up on members with the inability to fully participate in discussions (Mochizuki et al., 2003).

DEVELOPMENT OF THE I-BEE

Based on the method proposed above, the authors developed a CSCL software, referred to as i-Bee (Bulletin board Enrollee Envisioner), to visualize small-group (mainly asynchronous) discussions on BBS in real time. The i-Bee is a plug-in tool that works with discussion forums of exCampus and its databases, which is an e-learning module developed and distributed free of charge by the National Institute of Multimedia Education in Japan (Nakahara and Nishimori, 2003). It covers numerous functions necessary to build an e-learning site in a university—course management, learning management, interface for video streaming, discussion forums, etc.

The features of i-Bee have been discussed in the following section. The i-Bee has four features: (1) visualization of the relationship among keywords and learners in real time, (2) visualization of a time-series trajectory and snapshots at certain past periods, (3) visualization of recent levels of participation of learners and of recent frequency of keywords, and (4) location of messages containing corresponding keywords clicked as flowers by a learner on the i-Bee.

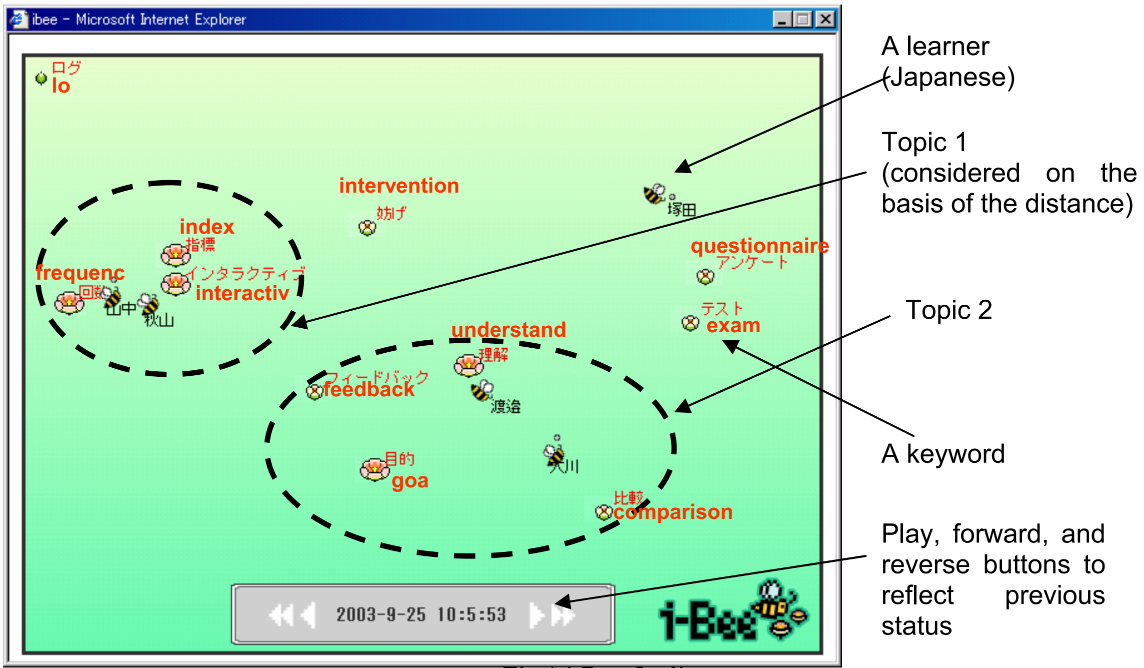


Fig.1 i-Bee Outline

(Arrows, circles, and English translations are not included in the original—only for explanatory purposes)

Real-time Visualization of Content-Wise Discussion

When a learner logs onto the BBS on exCampus, the i-Bee pops up as an additional window (Fig. 1). The i-Bee displays participating learners (bees) and keywords (flowers) selected by teachers. The distribution of the bees and flowers is based on the result of the CA conducted at that time. Each bee and flower is drawn with its name, which represents what is being described. The i-Bee refreshes the status not only when the learner logs in but also when the learner accesses every article; therefore, the i-Bee can display as new a status as possible.

While visualizing the coordinates, the i-Bee displays each bee turned toward the flowers as an indication of the number of times a learner uses the corresponding words. The angles of the bees are calculated based on the frequency and location of the flowers (see Table 1).

The i-Bee was developed for learners to recognize their status in the forums. Furthermore, it aimed at having learners reflect over their attitude in a discussion in a content-wise manner. In order for learners to appropriately assess their discussion, it is necessary to design a visualized image for them to easily recognize the overall image and their involvement in the discussion.

In order to address this issue, the authors adopted the “bees and flowers” metaphor to explain the co-occurrence relation between the learners and keywords in the discussion. Based on the algorithm of CA, strongly related elements should be located as coordinates in close proximity to each other. A comparison of the algorithm with the metaphor exhibits quite a resemblance—bees get drawn toward attractive flowers in order to

Table 1. Expressed Information and its Indexes, Targets, and Facial Expressions

Information	Index	Target	Facial Expression
What each learner talks	Coordinates calculated by CA	Distance between bees and flowers	The more a learner uses a certain keyword, the shorter the distance between the learner and the keyword.
Recent trend of keywords used by each learner	Weighted coordinate value of keywords calculated with the number of times each learner used the corresponding keywords recently	Head direction of bees	The more frequently a learner uses a certain keyword, the more the corresponding bee turns toward the corresponding keyword (however, the display is limited to angles of 45, 135, 180, 225, and 315 degrees)
Activeness of each learner	$i = \frac{number\_of\_the\_learner's\_articles\_at\_a\_certain\_period}{average\_number\_of\_the\_learner's\_articles\_per\_a\_period}$	Bee	$i \geq 1$: active bee $1 > i \geq$ threshold: normal flying bee threshold $> i$: sleeping bee
Activeness of each topic (keyword)	$i = \frac{frequency\_of\_the\_keyword\_used\_by\_all\_learners\_at\_a\_certain\_period}{average\_frequency\_of\_the\_keywords\_used\_by\_all\_learners\_per\_a\_period}$	Flower	$i \geq 1$: full bloom $1 > i \geq$ threshold: flowering period threshold $> i$: bud of flower

suck their nectar, while flowers require the bees to distribute their pollen. Thus, the learners can view the content and status of their discussion in the forum.

Visualization of the Discussion Process

A previous research indicated that learners can effectively reflect over their learning experience when a learning support system provides trajectories or snapshots of their learning at several points (Collins and Brown, 1988). Therefore, in order to promote an increased level of reflection by learners over their discussion, the authors developed i-Bee in order to allow learners to view their previous status and the process of change during the discussion.

When a learner accesses the i-Bee, it displays a trajectory of the learner's coordinates from the unit time t-1 to t before providing a snapshot at that time t (t is the number of unit time, which is calculated from the beginning until a certain point of time). Using the configuration tool, moderators such as teachers or teaching assistants are required to appropriately configure the unit of time in accordance with the learning activity. For example, if the course is conducted once a week, the teacher may set the unit time as one week.

Furthermore, learners can also view their previous status at every unit of time. In other words, learners can view their status of discussion as snapshots for one week before, one unit of time before, one unit of time after, or one week after by clicking on the operation buttons provided within the window of the i-Bee.

While displaying the animation and snapshots, the i-Bee fixes the coordinates of flowers (keywords) and mobilizes those of bees (learners) to naturally indicate the trajectory of how each learner (bee) has related with the keywords (flowers) and other learners (bees).

Visualization of Activeness

Learners and moderators face difficulties in understanding the status of discussion on the basis of the simple coordinates of bees and flowers produced by the CA since it does not display the recent amount of learner's participation and that of the appearance of the keywords in the discussion.

In order to visualize their activeness at certain points, the i-Bee displays bees and flowers at three levels (refer to Table 1): "sleeping bee," "normal flying bee," and "active flying bee" represent the possible facial expressions of the learner's recent level of participation. "Bud of flower," "flowering period," and "full bloom" represent the recent appearance of keywords indicating their frequency. The i-Bee calculates each learner's activeness as the proportion of his/her messages within the recent unit time to its average per unit of time. In the case of certain keywords, the i-Bee calculates their activeness as the proportion of frequency of the keywords used by all learners within the recent unit time to its average per unit of time.

Cooperation with exCampus Discussion Forums

The authors developed the i-Bee to cooperate with the discussion forums of exCampus. Learners can launch a search for messages containing certain keywords illustrated as flowers on the i-Bee. Hence, learners can easily locate interesting messages while viewing the i-Bee by clicking on the corresponding flower. Thus, i-Bee assists learners in locating interesting or surprising articles from large amount of messages.

Implementation

Figure 2 shows the workflow of the i-Bee. It requires a morpheme analysis system, e.g., "ChaSen" for Japanese text (Matsumoto et al., 2000), to calculate the frequency of each word from the text of the discussion.

In order to use the i-Bee in a course, moderators are required to set keywords using the configuration tool because the automatic keyword selection, which is based on a statistical analysis, cannot choose the appropriate words representing a discussion. The configuration tool allows only the moderators to modify settings (unit of time to organize frequency matrix, users whose articles are analyzed, users who use i-Bee, keyword selection, etc). These keywords are stored in the condition database.

In the keyword database, the frequency of keywords is stored along with the indexical information in the discussion, reflecting over the condition database. A database records the appearance of each keyword, using the following information:

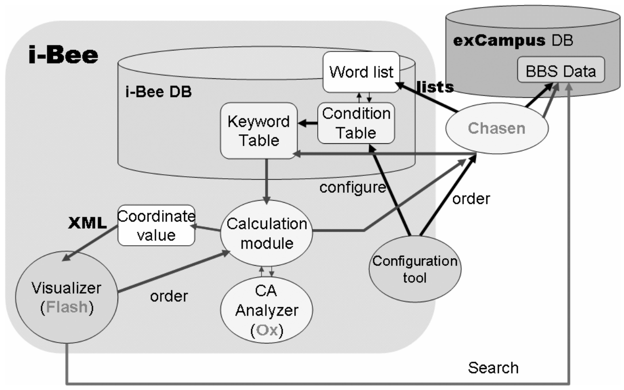


Fig.2. Workflow of the i-Bee

- Speaker/Author of the message in a certain period
- Total frequency of each keyword used in the messages by each speaker/author until a certain period

CA uses these data to construct a graphical display of the discussion profiles using Ox. Ox is a formula processing environment, which is an object-oriented matrix programming language with a comprehensive mathematical and statistical function library (Doomik, 2001).

The i-Bee procedure is as follows: Firstly, the learners or the moderators open the visualizer (Fig. 1), which was developed using Macromedia Flash MX, and the calculator orders the morpheme analysis system to calculate the appearance frequency of each keyword used by each learner until a given period of time. Upon receiving the result, the keyword database stores the frequency matrix. In order to display the status at a certain period or the previous status, CA calculates a matrix that conjugates one at the time t and another at the previous period t-1, as mentioned earlier. In other words, when n (l, t, w) is the accumulated frequency that the learner l uses the keyword w until the unit time t, $\boldsymbol{N}t$ is organized as below:

$$\underset{2L\times W}{N_t} = \begin{bmatrix} n(1,t-1,1) & \cdots & n(1,t-1,k) & \cdots & n(1,t-1,W) \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ n(l,t-1,1) & \cdots & n(i,t-1,w) & \cdots & n(i,t-1,W) \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ n(L,t-1,1) & \cdots & n(L,t-1,w) & \cdots & n(L,t-1,W) \\ n(1,t,1) & \cdots & n(1,t,w) & \cdots & n(1,t,W) \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ n(l,t,1) & \cdots & n(i,t,w) & \cdots & n(i,j,W) \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ n(L,t,1) & \cdots & n(L,t,w) & \cdots & n(L,t,W) \end{bmatrix}, where \quad l = 1,\cdots,L, t = 1,\cdots T, w = 1,\cdots,W$$

The calculator orders the Ox to analyze the data using CA. However, if a learner does not use any keywords or if a keyword does not appear at all, the operation is conducted with a matrix that omits the corresponding row or line from $\boldsymbol{N}t$ since the operation cannot be completed due to the zero-line or the zero-row. The analysis results in some value of the axis, and coordinates **F** and **G** are elected as the first and second axis of the result. The calculator transforms the value of the coordinates to an XML format, and the visualizer receives the data from the calculator.

The graphical display produced by CA shows the co-occurrence relation among participants and keywords. Learners can reflect over not only their condition in the group but also the flow of the discussion.

EVALUATION

Method of Evaluation

As described above, the authors developed the i-Bee to promote understanding in learners of their current condition and to reflect over the overall discussion. Majority of us agree that it is extremely difficult to grasp human higher-order thinking such as reflection or meta-cognition. Protocol analysis is one of the means by which to reveal the human internal condition; for example, what the subject recognizes and how the subject feels under a certain circumstance (Ericsson and Simon, 1993). Some researches in collaborative learning used protocol analysis through constructive interaction among their subjects to reveal how they recognized and reflected (Roschelle, 1992; Miyake, 1986; Shirouzu et al., 2003). According to these researches, the authors gave weight to ideas spoken by the subjects to understand how their cognition worked while the subjects used the i-Bee.

Course Outline

The class studied for an evaluation of the i-Bee was referred to as "Preservice Training 7," a winter term prerequisite course of 10 lectures in an undergraduate course for interns in elementary or junior high school in Japan. Nine seniors participated in the course. They underwent internship during the summer semester. The ultimate goal of the course was to reflect over their internship by preparing their teaching portfolios and discussing their experience on the BBS. The teacher, who placed emphasis on online discussions, requested the students to reflect their own opinion in their portfolios what they thought of during the discussion.

Discussion on the BBS was conducted for about 15 to 30 minutes at the beginning and the end of seven out of the 10 classes. In the first four out of the seven discussions, the students discussed their experience during the internship; in the next three discussions, they exchanged comments on each other's portfolios. Each topic was discussed in different forums and was independently analyzed by the i-Bee.

Data Collection

The authors observed a couple of students, Alice and Betty (fictitious names), using video cameras. They were both preparing their portfolios based on their internship in a junior high school, while they were engaged in both elementary and junior high schools. In the class, they usually sat adjacent to each other, as shown in Fig. 3. Their computer screens were also recorded using video cameras.

Fig. 3. A scene from the case
(Left: Alice; Right: Betty)

Even though the BBS supported asynchronous communication (i.e.,threaded discussion board), the students used the BBS synchronously during class hours. The reason is to collect their verbal data in a natural situation, in which they sat close together and verbally shared comments about what they saw on each of their i-Bee. However, the communication mode was partly asynchronous because the discussion was conducted across the lectures.

The first author participated in the course as a teaching assistant and recorded the data in five out of the ten classes. In the first class, the author sought the students' permission for data collection only for the purpose of the evaluation of i-Bee; they agreed.

The keywords for analysis with the i-Bee were selected on the basis of a consensus drawn between the teacher and the first author. They selected the keywords from messages with respect to the educational purpose, the learning context, and meaning of the keywords depending on the context of use. They altered the keywords based on the progress of the discussion. The selection process was conducted not only during class hours, but also mainly in intervals between the lectures. The thresholds for measuring the activeness of learners and keywords were 0.4 and 0.6, respectively.

RESULTS and DISCUSSION—HOW DID LEARNERS ASSESS WITH THE I-BEE?

The authors analyzed the videos and prepared transcripts based on them, including each utterance made by the students. A comparison of the screens with the utterance allowed the authors to study Alice and Betty's experience to recognize the representation of the i-Bee and the manner in which their recognition led to the progress of their discussion.

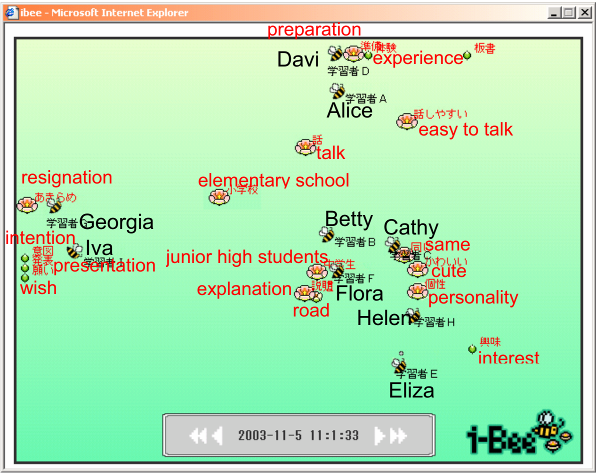
The results showed that (1) i-Bee can be a cognitive resource for learners to assess the conditions and (2) it can encourage learners to reflect and reorganize their learning activity by comparing their present status with their past status on the i-Bee.

In this study, the authors present two cases that prove the findings summarized above. For reasons of privacy, fictitious names have been assigned to the subjects used in the transcripts and figures. In the transcripts, the codes ":," "h," and empty double parentheses represent prolonged sounds, exhausted sounds, and unrecognizable utterances, respectively. Words enclosed in brackets indicate nonlinguistic action.

Providing Opportunities for Assessment of the Status of their Commitment in the Discussion

In this section, the authors describe the experience of the subjects to understand their commitment in comparison to that of other students. In this case, Alice found commonality with another student, as described below; it assisted her in communicating with a student she had not previously interacted with.

```
[Fragment 1]
[2006] Alice: Ah, here it is!
[2006] Betty: ((        )) same place as everyone else.
[2007] Alice: Yeah, I am near by David
[2009] Betty: You're right. ((           ))
[2011] Alice: Cathy is blurring again…hh…why is that? Why is it blurring?
[2017] Cathy: It's really sucking a lot of honey.
[2018] Alice: huhu hh: h
[2020] Alice: Might be poisoned!
[2021] Cathy: What should I do… it has a full stomach.
[2024] Alice: Hhhhh, this isn't good. (0.5) Eliza is still asleep.
[2029] Cathy: Ha hhhhh
[2030] Alice: And Flora is too. Wake up, wake up!
[2032] ? :    ((         ))
[2033] Alice: Ahahahahaha
[2034] Alice: Really?
```



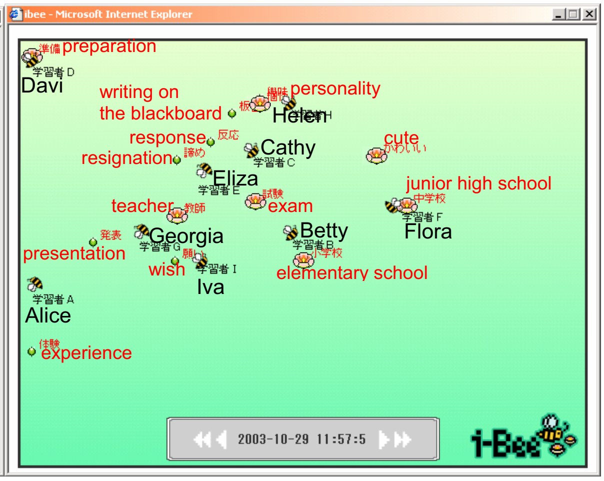


Fig. 4. Status of i-Bee at the time of Fragment 1 Fig. 5. Status of i-Bee at the time of Fragment 2

(Japanese words are original expressions. English translation is attached to each element)

```
[2038] Alice: "Preparing" and "experience" are there
[2043] Alice: It's friends with David
         [Alice changes screen to check David's remarks and reads his messages]
```

Figure 4 shows a representation of the i-Bee during the above-mentioned online discussion. In this fragment, Alice observed that her bee's location was closer to David's on the i-Bee, which is expressed by her statement, "Yeah, I am near by David" [2007]. She then began reading David's messages, which is expressed by her statement, "Its friends with David" [2043], although she did not pay much attention to his messages.

At this point, we must draw attention to one of Alice's statements, "'preparing' and 'experience' are there," [2038] before reading David's messages. Alice shifted her attention to "preparation" and "experience" although one observes the use of other phrases such as "easy to talk," "talk," etc. It appears reasonable to assume that she recognized commonality with David based on those two keywords at that time. In other words, the reason she began reading his messages was because she recognized commonality with him.

Stating that such an activity is a type of assessment of the discussion is not an exaggeration. Other similar fragments were observed in our research. Viewed in this light, the i-Bee can be regarded as a cognitive resource for learners to recognize their level of commitments, which encourages them to conduct assessments, particularly where they are less attentive.

Providing Opportunities for Reflection on the Discussion by Comparison with Past Status

The following fragment describes Alice and Betty's experience to reflect over their statements in a content-wise manner by understanding the change in their position on the i-Bee. Figure 5 shows the status of the i-Bee at that time.

```
[Fragment 2]
[4355] Betty: It's interesting.
[4356] Betty: I'm starting here. [clicking an icon on i-Bee with mouse]
[4363] Alice: Where am I? Oh, my bee is here.
[4366] Alice: It's here, but…I can't say I'm happy with where it is. (1.5) I'm in
         a slightly awkward location…
[4373] Alice: Aww…My bee has become further away from the others. I'm so lonely.
[4377] Alice: Hey, don't you think my bee is lonely and distant from the others?
[4378] Betty: Where?
[4380] Betty: I can't find you?
[4384] Betty: Oh, here you are, I see.
[4385] Alice: Yeah.
[4386] Betty: I'm here. As I predicted, I'm still at the "elementary school." I
         have to move on to "junior high school."
[4390] Alice: My location changed from the last time. It's near "experience" now
[4394] Betty: Oh, you're right, you're near "experience". h, h, hh
[4396] Alice: …but, the flower is wilted.
[4397] Betty: Big trouble for you!

                         — syncopation —

[4444] Betty: [She began to write a message titled "about junior high school
          students"]
```

As shown in Fig. 5, Alice's bee was located at a distance from the others, at a periclinal part of the mapping.

Alice stated, “I can’t say I’m happy with where it is,” “I’m in a slightly awkward location” [4366], and “I’m so lonely” [4373], moving her mouse cursor between her bee and others very quickly, immediately after finding her location [4366].

At this point, we should notice that Alice stated “my bee has become further away from the others” [4373] and “my location changed from the last time” [4390] in the transcript. These words “become further away” and “change” contain significance regarding the speaker’s recognition of the change in status. Briefly, it would not be possible for her to make such a statement without comparing her present status of the i-Bee with her past status.

Therefore, it is clear that Alice used negative phrases such as “a slightly awkward location,” “lonely and distant from the others,” [4377] etc. due to her recognition of the change in her status. These phrases are considered as her assessment for her bee that was located in a relatively undesirable position than before; this showed that she did not commit well to the discussion

Betty also assessed her location on the i-Bee in this fragment of conversation. It is noteworthy that she attempted to improve her condition expressed on the i-Bee on her own. At that time, as shown in Fig. 5, her location was closer to the “elementary school” and somewhat further away from “junior high school.”

She confirmed her location and stated, “As I predicted, I’m still at the ‘elementary school.’ I have to move on to ‘junior high school.’” [4386] She then began writing a message titled “about junior high school students,” which included her impression of the junior high school internship [4444].

In this case, similar to Alice’s, it may be stated beyond doubt that Betty remembered the previous location of her bee as being closer to the “elementary school.” She then “predicted” that the location scarcely differed from the previous one and confirmed as the above-mentioned scene. She then engaged herself in writing messages regarding “junior high school.”

Why did Betty state “I have to move on to ‘junior high school’”? At this point, we may recall their learning context, i.e., they prepared their portfolios based on their internship in junior high schools. Her position on the i-Bee expressed a lack of association between her commitment in the discussion and her practice in this course. Consequently, she became aware of this disjunction and changed her statement thereafter. It can be stated that such an activity on Betty’s part indicates self-assessment and improvement of her statement in the discussion.

All these statements clarify that the i-Bee can be a cognitive resource for learners to recognize a time-series change of state, which encourages them to assess their level of commitment to the topics or the whole of the discussion. Such recognition and assessment encourage learners to consider their level of participation at the meta-level.

CONCLUSION and FUTURE ISSUES

This study deals with self-assessment during a discussion, wherein learners can view the discussion, reflect in a content-wise manner, and reorganize their attitude in the discussion. The authors propose a method by which to visualize learners’ commitments to the content of a discussion and develop the software, i-Bee, which is implemented in the algorithm to encourage learners to assess their discussion. The evaluation elucidates that visualization of the discussion based on its contents should be a cognitive resource for learners to assess their learning through discussion along with observation of the difference between the status at that time and in the past.

Thus, the authors conclude that providing opportunities for such assessments and reflection encourages learners to improve their learning by comparing their learning context even in a collaborative learning setting.

Our final points should be covered in keeping with the future issues. The first issue is more precise analysis of the effect of the i-Bee, especially in the asynchronous situation, in order to reveal more concrete results which indicate how the i-Bee supports students. The second issue is with regard to selection of keywords. In order to assist even moderators such as teachers or assistants, a new method should be developed. This method should be able to satisfactorily select keywords for learners and teachers based on the learning context and from the viewpoint of social constructivism, which constitutes the basis of the collaborative learning theory. The third issue is with regard to the information provided by CSCL environments like the i-Bee. It can be said that providing awareness with regard to not only the discussion but also other social activities holds the possibility of encouraging learners to assess and improve their activities in the CSCL. However, this is only conjecture at this stage; we would like to empirically discuss in our future works.

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Designing for Constructionist Web-Based Knowledge Building

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Abstract. This paper describes the iterative design of a web-based collaborative workspace used in educational practice, called *WebReports*. The system's unique feature is that it allows participants to discuss mathematical and scientific concepts using programmed animated and interactive models of their ideas. Rather than focusing on the specific features of the collaboration tool, we analyze it as part of a constructionist activity system. We describe the context in which the system was developed and used and compare our approach to previous research in the field. Further, we then present two scenarios which demonstrate the system in action. Following that, we attempt to map our cases to an activity theory framework. We highlight several issues in the process of the systems' development, where the contradictions between the WebReports system and other elements in the activity system shaped its design, and comment on several issues which go beyond the activity theory framework.

Keywords: Iterative design; Design experiment; Web-based collaboration; Constructionism; Activity Theory;

INTRODUCTION: KNOWLEDGE BUILDING THROUGH CONSTRUCTION

WebLabs is a 3 year EU-funded educational research project oriented towards finding new ways of representing and expressing mathematical and scientific knowledge in communities of young learners[1]. Our work focuses on the iterative design of exploratory activities in domains such as numeric sequences, cardinality, probabilistic thinking, fundamental kinematics, and ecological systems. *WebLabs* utilizes two main media for its activities: *ToonTalk* (a programming environment) and *WebReports* (a web-based collaboration system).

One of the central aims of our work is to extend the idea of knowledge building. Building on the constructionist tradition (Papert & Harel, 1991; Hoyles & Noss, 1996) we combine software model construction activities with web-based collaborative knowledge building. By doing so we expand the range of communication forms learners have at their disposal. Participants can express their ideas as working models, and present these as representations of ideas and arguments in a discussion. Moreover, computational models also allow students to explore aspects of mathematics and science that were simply were not available to study in other representations. This possibility is especially powerful in a multi-cultural environment. When students lack a common spoken language, the availability of a common visual modelling language is an enabling factor for collaboration.

CSCL and knowledge building

A majority of the CSCL work focuses on sharing of knowledge through language. This fact limits the potential of incorporating knowledge expressed through non-verbal artefacts in the process of knowledge building. Moreover, there is an obvious problem with this if one wants to achieve interaction and knowledge building across European countries where students do not share a common spoken language. The paradigmatic computer support for knowledge building is the CSILE system (Scardamelia & Bereiter, 1996). CSILE is basically a discussion board where students can post notes on different topics and then comment on each other's notes. The first interesting aspect regarding the system is its close connection to the so-called knowledge building community model of education and learning. This model builds on sociological descriptions of how knowledge is created and refined in scientific communities (Latour, 1986). It describes learning as a process of collective

[1] http://www.weblabs.eu.com

construction of knowledge. Topics are discussed, elaborated, and continuously refined by a community of learners (or perhaps knowledge constructors). The mutual influences of individuals' actions within a community compel people to adapt to each other. Adaptation is not only a positive contribution to efficient knowledge building, but it is also a necessary requirement for a knowledge building community to arise at all.

CSILE's unique innovation was its scaffolding feature: a built-in structure which guides students to focus on particular knowledge building aspects of their discussions. These scaffolds include prompts that encourage students to clarify problem statements, develop theories, state difficulties in understanding certain issues, tag new information on a topic, and summarize what they have learned. Scaffolds are designed to structure the students' discourse to replicate the work of a scientific research team or a research community. Two issues that the extensive research of the use of CSILE in classrooms settings have shown is the need to focus on community building and on the organisation of learning activities aiming to achieve productive use of the technology (e.g. Hewitt, 2001; Hakkarainen, Lipponen & Järväla, 2001). These two issues have also been addressed in the work discussed in this paper.

Another well-known system based on the knowledge building model is KIE (Knowledge Integration Environment) (Linn, 1995). Whereas CSILE is domain independent, KIE is targeted towards science education and the particular properties of that domain. It is based on an educational model called Knowledge Integration. This model highlights conceptual change, focusing on fostering students' conceptual understanding of scientific phenomena as the integration of facts, argumentation, and evidence. KIE provides software scaffolding for students to build arguments (the SenseMaker component) and to collect and categorize pieces of evidence such as facts and notes in a reflective manner (the Mildred component). With the SenseMaker (Bell, 2002) component, students collect evidence that they connect to claims to either support or contradict the argument they are making, hence, models for scientific argumentation are combined with personal understandings. The Mildred component (Bell & Davis, 2000) focuses on the content of the evidence and the claims that are used to build the scientific arguments. A particular aspect is the meta-cognitive support which encourages students to reflect upon the information they are collecting in their projects.

Designing for systems of activity

Over the last decade, activity theory has been gaining attention as an aid for Human Computer Interaction (Nardi, 1996), CSCL, and the learning sciences in particular (Kaptelinin & Cole, 1997; Jonassen, 2000; Fjuk & Ludvigsen, 2001; Barab et al, 2002). Activity theory spans from the idea, put forth by Vygotsky (1962; 1987), that human actions are directed at *objects* and mediated by *artefacts*. These objects define the focus of our attention, while the mediating instruments shape our perception. Hence, the three form a minimal unit of analysis in understanding cognition and learning. Objects and instruments are artefacts of *culture*, developed through its *history*. A comprehensive analysis of an activity system needs to take these factors into account as well. Cognition and learning are always situated in socio-cultural contexts. Vygotsky's method is dialectic and emphasizes how the different components of the system shape and change one another; it builds on a Marxist tradition and on the ideas of Hegel.

These ideas have been elaborated by Engeström (1987; 1999) and Cole & Engeström (1993), to include the *community* in which the *subject* (acting agent) operates, the *outcomes*, or aims, of the activity, the *rules* which define the subjects relations with the community and the *division of labour* between subjects. Activity theory is never content with describing these constituents in isolation, but focuses on the relations and tensions between them. Indeed, learning is often driven by the need to resolve contradictions within the system.

The novelty of our project lies in the integration of constructionist modelling activities with web-based knowledge building discussions, to support learners distributed across six European countries. For us, this means looking beyond the isolated constituents of educational design, and exploring the *activity system* as a whole. This system includes a combination of components such as technological development, design of novel learning activities, and organizational efforts to support teachers and students in different countries. In the analysis we use activity theory due to its emphasis on understanding human action as systems of activity in social, cultural, and historical settings. By viewing our design efforts not only as particular technological developments (in the form of new ways to support model building and programming or a new system for collaboration) but also as the creation of a system consisting of new educational activities and organisational changes, we intend to show how all these components interact to form the system in which the students are central actors. This allows us a rich understanding of the educational context the students are working in. Note however, that this does not mean that technical developments are not important contributions of our work, but rather that these developments must be understood in the context of the activities and the settings in which they are used. By introducing new technologies in an activity system, the system itself is changed which may be the source of contradictions between the different components in the system. Fjuk & Ludvigsen (2001) discuss how contradictions in the use of such instruments arise from their multiple purposes, and how the particular purpose within one activity system is shaped by the activities that accompany the use of the instruments from another. They demonstrate how contradictions between the different purposes of an instrument may afford contradictory activities. Their analysis suggests that in order to understand the design of educational technologies we need to analyse these within the context of the activity and settings where they being used. This viewpoint has been a guiding element in the analysis of the present paper. Our system was designed in tandem with the educational activities, and the analysis is done in their context. These activities do not occur in a void; we need to be aware of a number of components of the activity system:

- The structure of the community (or communities) of researchers, teachers and students.
- The division of labour between these three groups and within them.
- The social rules which govern interactions between students and between students and teachers / researchers.
- The web of connections which tie local groups and global communities.
- Other instruments in the environment, such as the programming environment and spreadsheets, traditional tools, such as whiteboards and paper, as well as specifically designed objects for collaborative group activities.
- The mathematical and scientific objects which are explored and the educational outcomes of these explorations.

COMPONENTS OF THE WEBLABS ACTIVITY SYSTEM

In the following section we discuss the four central components involved designing the WebLabs activity system: the activity sequences, the WebReports system, the ToonTalk programming environment, and the educational and school settings that are involved in our work.

Activity sequences

Our methodology of activity design has emerged through a process of iterative refinement. Our approach interleaves modelling tasks and discussions (face-to-face and on-line). The former builds intuitions in the domain area, while the later forges these into formal argumentation. Our activities follow a common cycle: first a scientific phenomenon or research question is introduced via a group discussion and specific modelling tasks are derived from it. Students then work individually or in pairs, exploring the question at hand through modelling in ToonTalk. Once done, they use a specialized template to publish (on the web) a written report on their findings. The models they have developed are embedded in this report. These reports are then used as input for a group discussion, which concludes with the publication of a group report. When possible, this report will be reviewed by groups from other countries, working on the same topic, to initiate inter-group discussions.

The evolution of our methodology is in itself an interesting example of the mediating role of technology. At an early stage of the design, we realized that if we wanted to interleave on-line discussion with modelling, the WebReports system (described below) would have to support this practice. Among the required features were streamlined embedding of coded models in a textual report and templates which scaffold students' writing. Only after these features were available did we realize that they enabled us to create a new tool, and a new related practice, which we called *task templates*. These are report templates which include task instructions and questions. The novelty of this tool is that all the tools required for the task are embedded in the template. Students click on the tools they need, work their way through the modelling task, and eventually replace the question text in the template with their own observations.

The ToonTalk programming environment

We see software programming as playing a key role in individual and group learning. Children explore and test their conceptions of the phenomena through programming working models. Furthermore, by sharing programmed models, they communicate ideas in a concrete yet accurate form. We are programming with ToonTalk (Kahn, 1996; 1999; http://www.ToonTalk.com) a language used in the past with younger children to construct video games (Hoyles, Noss & Adamson, 2002). ToonTalk is a computer game, programming environment and programming language in one. In ToonTalk programs take the form of animated cartoon robots. Programming is done by training these robots: leading them through the task they are meant to perform. After training, programs are generalised by "erasing" superfluous detail from robots' "minds".

	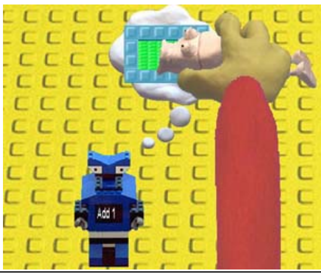	
Train the robot to take a number 1 from the toolbox and drop it on the input, to increment it.	Generalise the program by erasing the value of the input from the robots memory.	Give the robot its input box. The robot will continuously repeat the actions it has been taught.

Figure 1: Training a robot to count

Figure 1 shows three snapshots of what it means to write a program (train a robot) to count through the natural numbers. In fact, we only have to train the robot to "add 1" to a number and then *generalise* it to any number. The robot iterates the actions it was trained to do, for as long as the conditions it expects hold true.

The WebReports system

The individual and collaborative facets of learning are intertwined at all stages of our activities. The *WebReports* system (Figure 2) was set up to support both. The primary aim of this system is to allow learners to reflect on each others work by sharing working models of their ideas. The "atomic unit" of content in the system is a web report: a document containing formatted text, along with multi-media objects, Java applets, and most important – ToonTalk models. These models are embedded in the report as images, which link to the actual code object. When clicked, they automatically open in the reader's ToonTalk environment – which could be in another classroom or another country. The reader can then manipulate the object, modify it, and even respond with a comment that may include her own model. Note that by including a revised or alternative model the students have several ways of building on each others knowledge. This last point is crucial: rather than simply discussing what each other *thinks*, students can share what they have *built* and *rebuild* each others' attempts to model any given task or object.

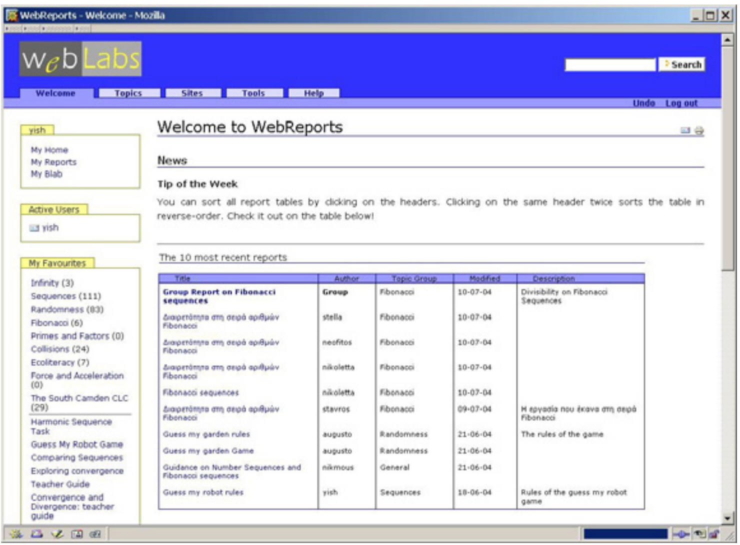

Figure 2: WebReports front page (http://www.weblabs.org.uk/wlplone/)

Since our primary focus was on the design of a system consisting of technology, activities, and organizational interventions we made a strategic decision to use (and enhance as needed) existing "vanilla flavour" open source systems. Our first prototype was built upon JSPWiki (http://www.jspwiki.org) whereas the current system is based on Plone (http://www.plone.org). This led us to focus on the functional and usability design, and minimize our implementation efforts.

Reports are edited using a visual editor. Apart from standard text formatting features, this editor allows users to easily embed media including Java applets of their models as well as objects embedding the ToonTalk code in their reports. Students can grab any program object in their ToonTalk environment, and copy it instantaneously into their report.

Reports are catalogued along three axes: topic, site and function. The first categorizes reports by their subject content (e.g. Infinity, Sequences, 1D collisions). The second lists the reports by the real-world team of the author (school, class or club). The function heading presents content by the way it was conceived to be used (programming component, personal report, tutorial etc.).

School settings

Working across six European countries means having to acknowledge more than language differences. We encounter a wide range of classroom cultures, practices and curricula, which all have to be accounted for in our design.

First, there are pragmatic issues: school times, session length, and firewalls. As mundane as they seem, these had an actual impact on the success of activities, primarily in cases where our design was in contradiction with existing rules.

One such example regards the use of web reports between sites. Our original plan was to have two groups work on a topic in parallel, publish concluding group reports, and then comment on each others' reports. In practice, synchronizing between sites proved impossible: even if one succeeded in scheduling an activity to start at the same time in both sites, the difference in session duration dictated by the local educational system meant that one group would be well into the next activity before the other published its concluding report. This realization led us to shift the emphasis to individual reports, as a means of collaborative knowledge building within groups.

Other issues are much more subtle, and relate to established classroom rules and norms regarding knowledge sharing. The first issue we encountered was that in most educational institutions, sharing knowledge goes against the grain of standard practice; often it is called cheating. This problem was easy to overcome. A much more difficult issue was getting students to publish work in rudimentary form. Our design builds on iterative refinement of knowledge through social interaction. This requires students to publish work that is not "correct" or finished, acknowledge public feedback, and republish. Again, this contradicts standard educational practice. In school, you submit a paper or exam when you think it is right, and the feedback you receive is judgmental.

To our surprise, the main hurdle in this case was put forth by teachers. In some cases, teachers found it hard to accept that students publish scientifically or mathematically incorrect texts for fear that this might be interpreted as a lack of proficiency on their side. Similar conflicts in norms and values will be further discussed below in order to illustrate how activity theory may support designers in understanding how aspects that might appear peripheral at initial stages of design later turn out to be the core challenges.

CASE STUDY EXAMPLES FROM SCIENCE EDUCATION ACTIVITIES WITH THE WEBLABS SYSTEM

Below we present two case study examples from our work. These two differ in several respects and have therefore been important to our understanding of the activity system as a whole. The first activity, called "Guess my robot", focuses on the intense collaboration and exchange between students in England and Bulgaria using small pieces of program code representing number sequences. The collaborative setting here works as a way for students to respond and act on each other's models on a day-to-day basis. The second activity, called "EcoModelling", focuses on students' illustration and presentation of their understanding of foodweb systems. Here, the collaborative setting has more of an indirect role but still significantly shapes the models that the students are building with less focus on day-to-day exchanges. Our analysis is aimed at identifying contradictions in the system. Contradictions are central to the development and changes of all activity systems (Engeström, 1987) and therefore useful as analytical tools (Fjuk & Ludvigsen, 2001).

A comprehensive analysis of the system would need to analyse more cases, comb them meticulously for contradictions, and resolve them by modifying the various aspects of the design. Such an undertaking would be far beyond the scope of this paper. We restrict ourselves to several of the more illustrative issues in each case.

Collaboration and "discussion" in the guess my robot activity

One of the activities we designed was the *Guess my Robot* (GmR) game. This game is a pivotal activity in our explorations of number sequences. Most students enter it with very little formal knowledge of sequences, and minimal ToonTalk experience. After GmR they move on to more advanced topics, such as the Fibonacci sequence, convergence and divergence, and cryptography. See Mor et al (2004) for a discussion of the mathematical-educational context of this game.

In this game, *proposers* train a robot to generate a numerical sequence, and publish its first few terms as a ToonTalk "box" in a WebReport, using a special purpose template. *Responders* build a robot that will produce this sequence, and thus show that they have worked out the underlying rule. As one girl said: "*So, like, the robot is my proof that I got it?*"

We first experimented with this activity in 2002/3 (Mor and Sendova, 2003). Our experience from this pilot informed both the design of the activity and of the WebReports system. In 2003/4 we expanded the experiment, with significantly greater response (Mor & Noss, 2004; Matos et al, 2004). This iteration included far more students and resulted in rich interactions.

We now analyze this case, using the activity theory framework as a guideline. We will focus on the role of the WebReports system, both as an instrument and as an arena for the activity. As mentioned above, the constituents of the system are not seen in isolation, but rather in relation to one another.

Outcome: The proposers' explicit outcome is the challenge, and the responders' the responses. Yet the game had additional implicit outcomes – the collaborative construction of knowledge about sequences. The WebReports system supports both, yet our activity design supported the former, but neglected the latter.

The explicit outcomes are embodied in models of number sequences, as ToonTalk boxes or robots. These can be seamlessly embedded in both challenge reports and response comments. The implicit outcomes are higher level abstractions and arguments about sequences. These are the more important outcomes from the educational viewpoint. They can be represented verbally, or as situated abstractions (Hoyles & Noss, 1996) by ToonTalk models. The system is flexible enough to support both. However, we failed to design the activity in a way that would promote them and make them explicit. To use Wenger's terminology (1998), we failed to foster a sense of joint enterprise (although, in some exceptional cases, this sense emerged from the students' initiatives).

Subject: We wish to focus on two relationships – that between subject and instruments, and that between subject and community.

On the issue of subject and tools, we find Ivan Illich's notion of conviviality a useful benchmark:

> Convivial tools are those which give each person who uses them the greatest opportunity to enrich the environment with the fruits of his or her vision… Tools foster conviviality to the extent to which they can be easily used, by anybody, as often or as seldom as desired, for the accomplishment of a purpose chosen by the user… They allow the user to express his meaning in action. (Illich, 1973)

Students developed a convivial attitude towards ToonTalk. They used it in ways we had not expected, to test conjectures and express mathematical arguments (Mor & Noss, 2004). However, while some students (and teachers) approached the WebReports with conviviality, bending it to their needs and expressing themselves freely with whatever means it provides, others did not. Students' inability to post challenges and responses in the prescribed way hampered collaboration and undermined the success of the activity. We see the causes in two other aspects of the activity system: insufficient attention to the rules imposed by local settings, and a lack of investment in the roles of facilitation and tutoring.

Object: The objects in focus were numeric sequences. Having those as the play-things in the game eliminated a contradiction often found in educational games, where the learning objects are exogenous to the activity (Squire, 2002).

Instruments: Access to the mathematical objects was mediated by the computational media: ToonTalk programming and Excel worksheets. Each one has its own affordances and constraints. While ToonTalk allows the students to construct surprisingly complex sequences, in many cases they preferred to use Excel as an analytic tool. We are not sure whether this preference originated with the students, or reflected the techno-cultural background of their teachers. ToonTalk's mediating role was facilitated by the WebReports streamlined embedding of models in report text.

Rules: Engeström (1987) identifies rules as mediating between the subject and the community. In our case, the main design challenge of GmR was setting the rules of the game. These rules cannot be designed in isolation – they need to acknowledge existing rules: those which regulate the social system of the classroom, and those which are constructed when students engage with remote peers. In fact, we had supplied the students with very little other than these rules. The activity is defined by the roles of proposer, responder and their protocol of interaction. Indeed, when these rules were observed, the activity followed a productive path. To our disappointment, this happened in less then half the cases (21 out 45 challenges and 15 of 33 responses). We read a very strong message here, which relates to the issue of division of labour, discussed below.

The design of GmR demonstrates a relation which is not usually observed: the mediating role of technology in the construction of rules and their relationship with subjects and objects. As an example, the communication afforded by a web-based system is very sparse compared to face-to-face interaction. This meant that for interactions to be successful, each utterance had to be rich in content. In part, this limitation was overcome by a virtue of the tools: the animated code fragments participants embedded in their texts served as avatars, or proxies, in delivering their ideas.

Division of labour: As mentioned above, the success of the activity was impeded by participants' failure to adhere to its rules. This failure was a result of a contradiction between the designed rules and those which participants had appropriated in common classroom practices. For instance, the emphasis on using code fragments as an element of communication was a completely novelty. In vernacular activity systems, the rules are transparent: they are maintained by consensus of the community, and new members learn them by *Legitimate Peripheral Participation* (Lave & Wenger, 1991). In designed activity systems – such as ours – the rules need to be consciously accepted by all members of the community at once. This creates the need for a *facilitator*, a person whose role is to monitor adherence to the rules. The facilitator regularly scanned the WebReports system for GmR contributions. When they were ill-formed, he would alert the authors to their mistakes, and guide them in correcting them. In other cases he would point participants to contributions which they would find interesting – an action that would have not been necessary had the authors of these contributions observed the rules.

Construction and presentation of eco-system models - EcoModelling

The EcoModelling activity sequence focused on allowing students (5th grade) to program their own models of food webs where an endangered species plays a central role. The students chose to focus on animals such as the giant panda, killer whales, and Siberian white tigers. The specification of the activity sequence include on as well as off the computer activities where students design, program and discuss their models. The activity sequence was presented to the students as having the goal of producing models that could be published as WebReports and that others could try out, discuss, and comment upon. The students also used the WebReports system to report on their progress in the form of diaries that include partial models of the phenomena they are working with.

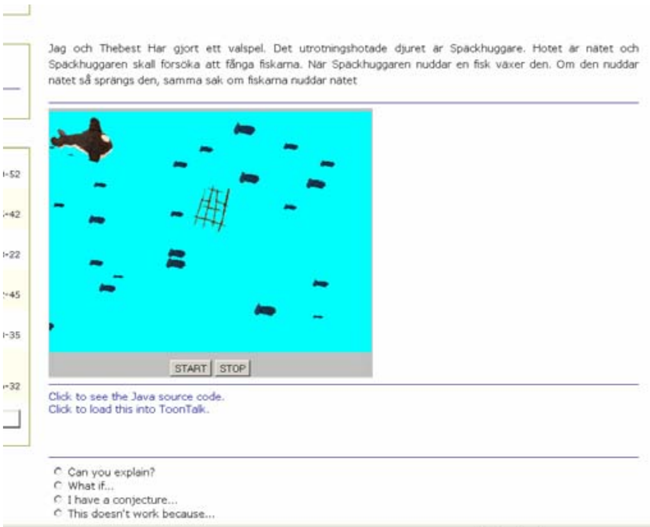

Figure 3: The Whale game by two students exploring the life conditions of killer whales

"I and The Best have made a whalegame. The endangered species is the killer whale. The threat is the net. The killer whale is supposed to try to catch the fish. When the killer whale touches a fish it grows. If it touches the net it blows up, same thing if the fish touch the net"

Goals of activity sequence: The practice that we aimed to stimulate in this activity sequence was twofold. First, to support students in constructing models of their ideas and knowledge about ecological systems. Second, for students to publish their models of these along with textual explanations and description. Receiving students would analyse the models and modify and comment upon these. The intended outcome would thereby be the *joint enterprise* of knowledge production of ecological phenomena. The two central mediating instruments in the production of models and knowledge are the programming tools used for building models and the WebReports system used for publishing models, and commenting and discussing these. These instruments serve dual purposes, both to shape the artefacts but also as mediators in the production of knowledge. Therefore, the students were engaged in two different roles throughout the activities, both as producers of models of ecological systems and as actors in the knowledge production community that we aimed to promote. Moreover, these two roles also occurred at two different levels of collaboration; both at the level of individuals and small groups producing models, and at the community level of knowledge building using the WebReports system.

Community, rules, and norms: The students' model construction and sharing were significantly influenced by the international setting. This was the case even though at the time of this study the WebReports system was just recently up and running so collaboration with students from the other countries only happened to a limited extend. Here, we would like to focus on two relationships that we identified as important sources of the contradiction in the activity system: the relations between subjects and the surrounding community and the relations between subjects and rules and norms. The relation between the students and the surrounding community influenced the models that the students produced as well as the final outcome of the activity in two ways. *First*, the nearby group participants actively contributed to the shaping of the models that the students produced through discussions and comments that occurred in local activities and through use of the WebReport system. Moreover, the local community also affected the students through their own social relationships. This indirectly shaped the final outcome in that students were highly engaged in the particular impressions their models would make on other local community members. The following fragment illustrates this issue. The four students are discussing the model that is being built by two of their friends (Sebastian and Jonathan) which aims to illustrate how a drought may influence the life conditions of rats and sunflowers. Throughout this episode the students have quite a critical tone towards their friends' model.

1. *Tobbe: Their huge sun flower in the middle of the screen is…*
2. *Jonna: Really, seriously speaking their sun flower is kind of …*
3. *Tobbe: The rat is not really that pretty either, do you think*
4. *Tina: Yeah, I thought that*

…

5. *Mimmi: Tina please let our buffalo be part of your game*

The most important thing that happens in this episode is not how the students exchange specific ideas about how to implement a phenomenon in their models, nor that they find specific suggestions relevant to their own work by studying what their friends are doing. Instead, what we find to be most important is that the students relate to and compare what they are doing to the work of their friends on a social level. Most of the influence of the collaboration does not concern the specific scientific content of the models they are building. It is rather about comparing and discussing each one's work in relation to everyone's overall progression. There is also extensive engagement in making sure that what they are building complies with the agreed upon overall norm for what they find the activity to be about. The two girls, Mimmi and Jonna, here come over to Tina and Tobbe to compare with their own work, to discuss the work of the Sebastian and Jonathan, and to try out the game that Tina and Tobbe have built. Hence, the role played by social influences for the modelling and programming of their system is mostly as a motivator for the progression of the activity as a whole, rather than having implications for specific considerations concerning knowledge about modelling of ecosystems.

Second, even though there was only limited immediate interaction between groups of students in different sites, the student's awareness of a larger community significantly influenced how they approached the production of ecosystem models. This relates to a contradiction that we identified in the different ways that the WebReports system may be used. In the EcoModelling activities the students mostly used WebReports as a tool for presentation of the models they had produced (see Figure 3) and much less as a tool for discussion and sharing of knowledge. This is a consequence of a contradiction between the goals that students developed in local group activities and goals at the community level. We see this as an example of a more general issue: the contradictions between motives and goals of the different actors (students and teachers) within educational activities. In our case the students' motives were partly to jointly discuss their ideas and thereby be co-producers of knowledge. However, we discovered that for the students, the goals of joint knowledge production often stood in contrast to the more immediate goal of actually designing and implementing their models in the programming tools with their peer students as the particular audience. These two goals are different in character and may therefore subsequently lead to a different set of sub-activities; the practical activity producing a working computational artefact vs. the activity of discussing the ideas that the artefact represents.

This contradiction has important consequences not only for the activities that students engage in but also for how we as designers of the system should approach the redesign of the different components and sub-activities. We see that a significant source of this contradiction is found in the underlying values of these two activities. The model construction activity has a clear resemblance to the established practice of schooling: performing a task by following instructions, which here involved building a model using this particular tool. On the contrary, knowledge building as a joint activity requires the fostering of a new set of social rules and norms for what the school activity should be about. To resolving these contradictions we would need to redesign the WebReports system and the activity sequence, and also to raise awareness of the unorthodox rules we wish to establish.

CONCLUDING DISCUSSION

We have reviewed two examples of educational activities designed and tested by the WebLabs project. While both cases were fairly successful, they both had their weaknesses. These activities differ in their knowledge domains, but also in how different aspects of of Knowledge Building and Constructionism took form. While GmR had various elements of the traditional knowledge building interactions, EcoModelling focussed more on model building and presentation. GmR used ToonTalk's low level programming facilities, whereas EcoModelling applied a component-based approach. In GmR WebReports served as a platform for discussion, in EcoModelling they functioned primarily as a display medium.

A key result concerns how the students perceived the expected outcome of the different activities in the two case studies. In the EcoModelling activity the students mainly focused on creating their models and presenting them to their peers, both over the web and in group presentations. Thereby, the web-based collaboration did not become an aspect of the actual model building activity. In the Guess my Robot activity on the other hand, the students focused on using the WebReports system to create challenges and respond to each others challenges, and the intense web-based collaboration became a prerequisite for successfully engaging in the game. Thereby, the web-based collaboration provided additional benefits to the outcome of the activity as a whole which local collaboration would not have afforded.

In both our case study examples we saw how the goal of the technologies that we have designed sometimes contrasted with existing classroom practices. The two technologies also introduced a few conflicting goals. Hence, design efforts to a large extent involved helping students and teachers to find ways to incorporate these technologies into their classroom practices. The changes and extensions we made to our systems were hence always accompanied by changes to the activity sequences, particularly as the kind of activity we aimed to foster involved a range of different social (schools, research practice, virtual places) and technological contexts (websystems, programming tools). It has been central to our design efforts to always take this range of aspects into account.

Three themes are common to all our other activity sequences and contributed to their success:

- An attempt to blend ideas of knowledge building, as a social practice, with constructionist modelling, as an individual (or small-group) endeavour.
- A view of designing, and analyzing, the epistemic activity system as a whole: the tasks, their aims, the tools (ToonTalk programming and WebReports collaboration), school settings and community practices.
- An iterative process, in which the activity system evolves through cycles of design, critical evaluation and refinement.

These themes are tightly bound together. An activity-theoretic view leads us to the understanding that the individual-cognitive and social factors of learning are intertwined. In our case, these are reflected as construction and discussion. It also suggests that the historical process of refinement (even at the micro-level of iterative design) is inevitable; Instruments, both concrete and social, are invented for a purpose – but their full potential is realized through use. In our case, testing the activity sequences with one version of the tools led to insights regarding the refinement of both the tools and the activity design.

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Explicit Referencing in Chat Supports Collaborative Learning

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Abstract. In Pfister & Mühlpfordt (2002) a study was presented showing that chat discussions with a strict turn order combined with the requirement to assign a type and an explicit reference to each message lead to a higher learning score than discussions in a normal chat or in a chat with strict turn order only. Due to the experimental design it was not possible to judge the role of explicit referencing. Now we present the "missing" data: The higher learning score can be explained just by the explicit referencing. We argue that this is an important design issue for chat applications, because it seems that explicit referencing leads to a more homogeneous discourse behavior (more homogeneous participation, more participation in parallel discussion threads) and a better grounding. A case study explored the use of the referencing function in a less restricted everyday collaborative situation.

Keywords: CSCL, Chat, Referencing, Experimental Study, Case Study

INTRODUCTION

Collaborative learning relies on successful communication. Successful means that the collaborators understand each other's contributions and build a shared understanding of the collaboration content. When the group communicates using chat, the communication is influenced by the medial properties. A prominent phenomenon of chat communication is the somewhat "chaotic" discourse structure: Often the group discusses two or more topics in parallel, and related turns are in contrast to spoken conversations not adjacent. Another important requirement for effective collaborative learning is the combination of communication with shared artifacts (artifact centered discourse; Suthers & Xu, 2002).

In this paper, we propose that extending the medium chat with the possibility to assign explicit references to a message and to shared material supports the group in their discourse.

The remainder of the paper is structured as follows. In the next section, grounding and discourse comprehension are presented as a theoretical basis for explicit referencing. Then we present an empirical study, which shows that explicit referencing results in a higher learning score. A post-hoc analysis of the discourses indicates that grounding is supported by explicit references (section 3). To explore acceptance and usage of explicit references in less restricted chats, we conducted a case study in an everyday collaborative situation, which is presented in section 4. In section 5 we compare our approach to related work. Finally, we conclude with a discussion of the results and identify open research questions.

THEORETICAL BACKGROUND

In this section, we present some theoretical background for the explicit referencing. We argue that explicit referencing influences the grounding strategies of the communication partners and eases the process of discourse comprehension. Therefore, we shortly present the concept of grounding and theories of discourse comprehension. Then we discuss findings of chat research in respect to these aspects. Finally we describe the concept of explicit referencing in more detail.

Grounding

Building a common ground is an integral part of collaborative learning (Baker et al., 1999). The communication partners construct a shared understanding of what is said by giving mutual feedback. They reciprocally ensure each other that the ongoing discourse builds on and extends shared knowledge. Only the contributions that are grounded (mutually believed to be understood) become part of that shared knowledge, the so-called common ground (Clark, 1996). For achieving and maintaining the common ground in spoken face-to-face communication, various forms of linguistic and non-linguistic feedback are used. People use methods like giving oral feedback (e.g. “hm”), non-verbal attention cues (e.g. eye contact), or initiating turn-taking (e.g.

asking a question) for grounding. Mostly, positive feedback that an utterance is understood is given simultaneously without interrupting the speaker's turn.

The effort for grounding required by the participants varies with the properties of the communication medium (Clark & Brennan, 1991). The medium constrains the communication and thereby influences the costs of grounding. For instance, the medium may constrain the people with respect to cotemporality (Can the production of an utterance be perceived by the communication partners roughly at the same time?) or sequentiality (Can the turns get out of sequence?).

Following the principle of least collaborative effort, that "in a conversation the participants try to minimize their collaborative effort – the work that both do from initiation of each contribution to its mutual acceptance" (Clark & Brennan, 1991, p. 135), different media result in different styles of grounding.

Discourse comprehension

The concept of grounding describes the mechanisms used by the communication partners to ensure and keep track of the mutual understanding. Theories about discourse comprehension try to explain how people comprehend, what others say. An important aspect of the comprehension process is to infer the relation – the local coherence – of the utterance to the surrounding discourse (Hobbs, 1985). Elliptic and anaphoric expressions refer back to objects introduced earlier in the discourse, and descriptive referential expressions point directly to a previous utterance or paraphrase it (Eklundh & Rodriguez, 2004). This inference process can be treated as problem solving to arrive at the speaker's intended interpretation (Clark, 1978).

Chat research

Chat is widely used to do conversations online. From the linguistic perspective chat-conversations share some features of oral language although it is a textual medium (Koch & Österreicher, 1994), like accepting surface errors (syntax and grammar), using informal phrases etc. It is claimed that this results from the similarities between the communication situations (Murray, 2000), more specifically from the communicative attitude in a spoken face-to-face communication and a chat conversation. Nevertheless, the medial properties of chat lead to discourse structures that are different to the ones of from spoken face-to-face conversations. These medial properties are:

1. Separation of production and presentation: The production of an utterance (chat message) cannot be perceived by the communication partners. The message is presented to them as a whole only after it has been sent by the contributor.
2. Sequencing of messages: The contributor cannot determine the exact position of a message, which depends on the simultaneous (not observable) communication behavior of the communication partners.

As a consequence, the sequential order of the messages is characterized by disrupted turn adjacency (Herring, 1999). This complicates the identification of the message, the new one is responding to and leads to so-called phantom adjacency pairs, i.e. pairs of subsequent messages that seem to be related, but are not intentionally related (Garcia & Jacobs, 1998). Another consequence is the lack on simultaneous feedback, which is especially important for the grounding strategies in spoken communication.

Facing these problems chat users adapt their communication strategies: For instance (1) a turn is broken down in a sequence of messages, indicating at the end of the message, that it is going to be continued (Herring, 1999). (2) The addressee of the message is explicitly mentioned. (3) Responses to messages of parallel ongoing threads are done with different messages, preserving the "inner-thread" sequential order (O'Neill & Martin, 2003). This shifts at least partially the costs from understanding to production of a message.

Concept of Explicit Referencing

Explicit referencing means that while producing a message an object in the shared environment can be selected and assigned as a referential point to that message. We call the (directed) relation between the message and this referential point a reference. This reference is transmitted together with the chat message and visualized as an arrow starting at the message and pointing to the referential point. A previous message, a portion of it, or some part of a material viewed in the shared environment can be selected as referential point. When receiving a message, the reference is automatically shown. The reference of a previous message can be made visible by selecting that message (see reference from a contribution to a part of the shared material in fig. 1).

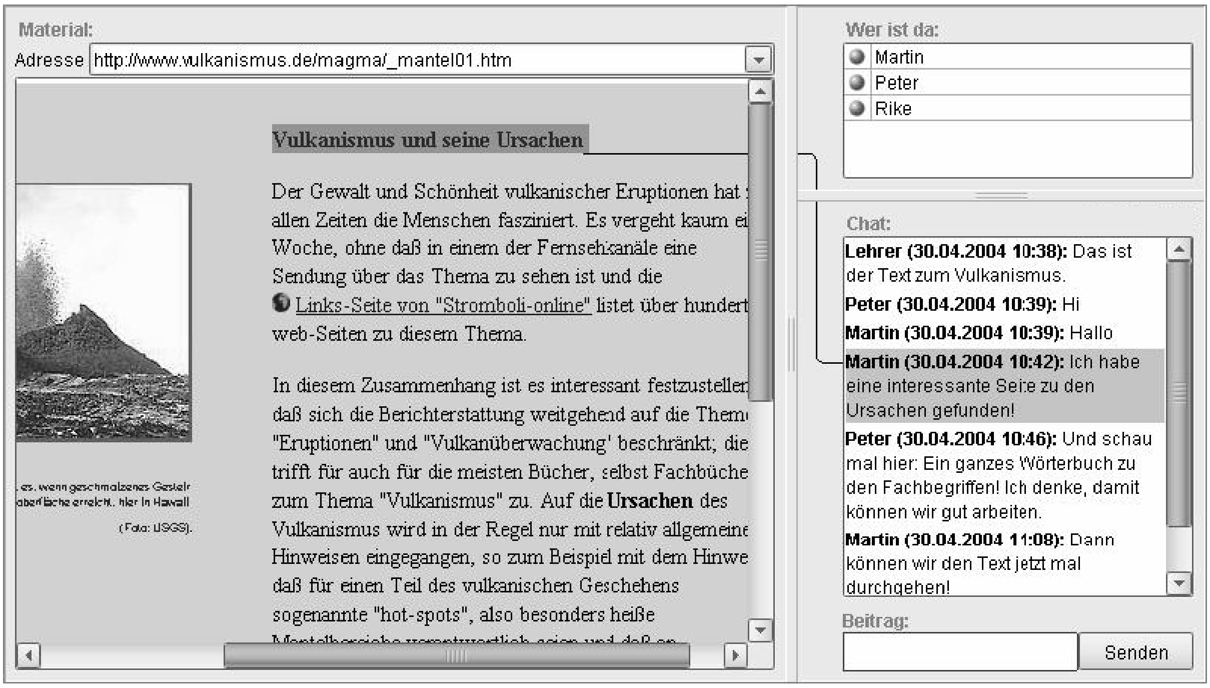

Figure 1: Showing a reference from an old message pointing into the material.

We expect that explicit referencing influences the communication in the following ways:

1. Message comprehension: The inference of a message's relation to the surrounding discourse (including other messages and shared material) is simplified.
2. Message production: As the costs of understanding a non-adjacent message are reduced, participants are encouraged to respond also to older messages. This leads to more grounding activities, e.g. acknowlegding previous messages. In addition, referencing to shared material saves production costs as effort to repeat or describe parts of the material is reduced.

EFFECT OF EXPLICIT REFERENCING TO LEARNING SUCCESS

In a prior study (Pfister, Mühlpfordt & Müller, 2003, preliminary results were presented in Pfister & Mühlpfordt, 2002), the effect of system controlled so-called learning protocols on learning was explored. In that study, the learning protocol controlled the turn order with only one participant contributing at a time.

In this study, learning under three different conditions was compared. (1) The complete protocol condition. Here, the participants were forced to create an explicit reference before actually writing the message, and the turn order was system controlled. (2) The chat application used for the second condition didn't have the referencing function, but the strict turn order was applied. (3) The control condition. Here, the participants used a normal chat tool without referencing and without turn control.

Three different group sizes (dyads, triads, and quartets) and two different learning domains (causes and consequences and different types of earthquakes vs. difference between to opine, to belief and to know) were tested. The study showed for the earthquake domain superior learning across the different group sizes under the complete protocol condition, and no effect of the strict turn order without referencing. Because of the design of that study, it was not possible to check whether the superior learning was due to the explicit referencing alone or the combination of both, strict turn control and explicit referencing. Therefore we extended that study by the missing forth condition: learning without strict turn control and with explicit referencing.

Method

We decided to check only triads and quartets, because we expected that the impact of the explicit referencing is low for dyads as only one other participant can disrupt the sequential turn order. Furthermore, we focused on the earthquake domain, which previously has shown a clear effect. Together with the conditions of the prior study, we have a three factorial between-subjects design with the factors *Turn-Control* (with and without), *Referencing* (with and without), and *Group Size* (triads and quartets).

A total of 31 subjects (students of the Technical University of Darmstadt) participated in the study, put together in 5 groups of 3 and 4 groups of 4. Participants received 15 Euro for participation in a one-hour session. The sessions were organized according to the prior study: The learners and the tutor worked with standard PCs in isolated cubicles (i.e. they could not see each other), simulating a distributed scenario. First, the general scenario was introduced, a short questionnaire about experience with computers and the internet was administered, and the user interface of the chat tool was explained. The participants learned how to refer to previous messages and the material and how the messages are actually written and sent. Then, a short knowledge test was applied to assess participants' degree of prior knowledge. The test consisted of one open question ("Explain shortly how earthquakes evolve."). Then, the participants started with the learning process. A learning goal was provided and presented on a sheet of paper attached to the PC. The learning goal was "to understand causes and consequences of earthquakes and different types of earthquakes". The time limit for a learning session was 25 minutes. The tutor monitored the messages and whenever a message could be identified as a question containing a key concept, the standardized answer was given; else, the tutor did not join the discussion. Directly following each learning session, a knowledge test was applied to assess participants' degree of knowledge after the session. The knowledge test consisted of a number of multiple choice items and one open question.

		Without Referencing	With Referencing	Total
Without Turn-Control	Triad	15 (5)	15 (5)	30 (10)
	Quartet	16 (4)	16 (4)	32 (8)
With Turn-Control	Triad	15 (5)	15 (5)	30 (10)
	Quartet	16 (4)	12 (3)	28 (7)
	Total	62 (18)	59 (17)	121 (35)

Table 1: Number of participants (groups) per condition.

Results

The data from the 90 subjects of the prior study and the data of the 31 new subjects were analyzed together (for distribution of subjects to conditions see table 1). The effect of the three factors *Referencing*, *Turn-Control* and *Group Size* was tested with a three factorial covariance analysis with the test score of the knowledge tests as the dependent variable (range 0 to 17) and the test score of the pretest as covariate. The ANCOVA revealed a reliable main effect of *Referencing* $F(1,111)=9.9$, $p<.01$. Neither the other main effects (*Turn-Control* and *Group Size*) nor the interactions were reliable (see figure 2 for mean and standard deviation of the raw data).

		Explicit Referencing								
		Without			With			Total		
Group Size		Turn-Control			Turn-Control			Turn-Control		
		Without	With	Total	Without	With	Total	Without	With	Total
Triad	mean	9.83	9.87	9.85	10.36	10.21	10.29	10.09	10.02	10.05
	SD	2.48	2.16	2.28	2.10	2.15	2.08	2.28	2.12	2.18
Quartet	mean	9.19	8.63	8.91	10.13	11.84	10.98	9.66	10.23	9.95
	SD	2.32	2.70	2.49	2.55	2.19	2.50	2.44	2.92	2.69
Total	mean	9.50	9.23	9.36	10.23	11.14	10.67	9.86	10.14	10.00
	SD	2.38	2.50	2.42	2.31	2.28	2.33	2.36	2.57	2.46

Table 2: Mean and standard deviation per condition.

Discussion

The conducted study shows that explicit referencing leads to a higher learning score. Applying a strict turn-control, allowing only one participant to write at a time, has no reliable positive effect.

THE EFFECTS OF DIRECT REFERENCING – POST-HOC ANALYSIS

The post-hoc analysis aims to show evidence for the proposed effects of explicit referencing on the grounding strategies. In the analysis we include only the chat logs of the groups communicating without turn control.

The analysis faces two problems. First, changing the analysis level from individual to group data results in a sample of only 18 discourses, 9 per condition, 5 from triads and 4 from quartets. Because of this small number we cannot use statistical tests. The second problem is the heterogeneity of the discourses. For example, the length of the chats varies between 25 and 178 messages for the Without Referencing condition and between 35 and 73 for the With Referencing condition. Therefore, we present only descriptive data, but we think that this illustrates the changes in the communication strategies due to the explicit referencing and gives valuable hints for further research.

Generally, the discourses are topic-centered and task-related. 95% of the learners' messages (947 out of 993) are related to the earthquake-topic, especially to the different aspects of the learning goal. The 5% off-topic messages deal mainly with the coordination of the chat. In 12 out of 18 chats less than two off-topic messages occurred at all.

We propose that explicit referencing changes the grounding strategies, because the explicit relation to the surrounding discourse should reduce the costs for understanding a message (Clark & Brennan). This should affect the participants in two ways:

1. The pressure to keep the messages “near adjacent” should be lowered. That is, participants might be more willing to respond to older messages. As indicators for this, we counted the number of intervening messages between message-response-pairs. The analysis shows that in the discourses without explicit referencing nearly 34% of the messages-response-pairs are adjacent compared to 24% in the discourse with explicit referencing. The number of message-response-pairs with 4 or more intervening messages raises from 18% to 26% (see figure 2).

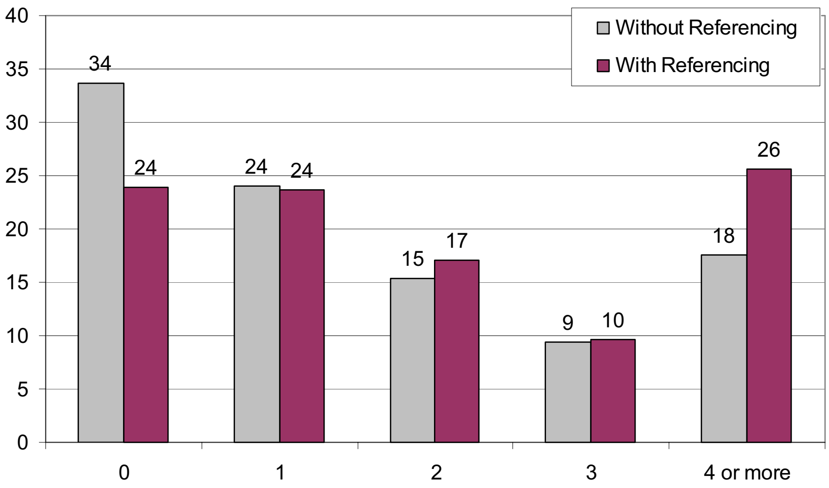

Figure 2: Mean percentage of messages per message-response-distance

2. The tendency to send affirmative feedback should be raised. As an indicator for this we counted all messages that had no response, assuming that the affirmative feedback is not again commented. In the discourses without explicit referencing 35% of the messages have no identifiable direct response compared to 43% of the messages in the discourses with explicit referencing (see table 3).

	Triads	Quartets	
Without	32.6	37.7	34.9
With	41.0	45.5	43.0

Table 3: Mean percentage of messages without response per discourse

Beside the changes in the strategies, we expected that the number of misinterpretations should be lowered. As indicator, we counted all observable situations where a participant misinterpreted a message. The analysis showed that there were quite few such situations: In the discourses without explicit referencing in 4 out of the 9 discourses 9 such situations could be identified, none in the discourses with explicit referencing.

USAGES OF EXPLICITE REFERENCING – A CASE-STUDY

In the design of the study presented above, some conditions were quite artificial and do not match the conditions in everyday collaborative situations. The participants of the study had no real interest in the topic, were paid, were assigned randomly to the groups, didn’t know each other, had no or limited common ground, and were forced to set an explicit reference for each of their contributions. In addition, in one condition they had to follow a defined turn taking method.

These restrictions to the chat communication are expected to lead to a communication style different from non-restricted communication. For example, we saw in the evaluation of the chat log that some participants circumvented the original idea of the referencing by just setting a reference to the complete material. This is the type of reference that requires the least effort; it is done with a right mouse click at any position in the material. In the following case study, our goal is to find out how groups use the referencing functionality in everyday collaborative situations. We expected that users use references mainly to indicate the responds-to relation between two messages and to a lower extent to point to specific parts in the shared material (deictic use).

Method

We announced a chat session in a team meeting of our research group at Fraunhofer IPSI. The topic of the chat session belonged to ongoing planning work in the research group. The group should generate and discuss scenarios to combine concepts and technology from two projects currently running in our group. These were the DIGITAL MODERATION project, which develops a system to facilitate face-to-face workshops, and the ConcertChat project, which develops chat tools with additional features such as shared material and explicit referencing (for example the tool used in this study). Four research associates volunteered to participate in the chat session with the proposed topic. All participants had an academic background in computer science (3) or information science (1). None had used a chat tool with referencing functionality before.

In comparison to the preceding study, the tool differed in the following aspects: (1) There was no turn-taking regulation. (2) Users were free to use the referencing functionality. (3) They could define multiple references for each contribution, e.g., refer to two or more previous contributions or to refer to contributions and places in the shared material.

Figure 3 shows a screenshot of the tool: In the left part of the window the shared material is presented. The upper right part presents a list of all persons currently online. Below is the scrollable list of all chat contributions and in the lower right part the interface to enter and send a new contribution is located.

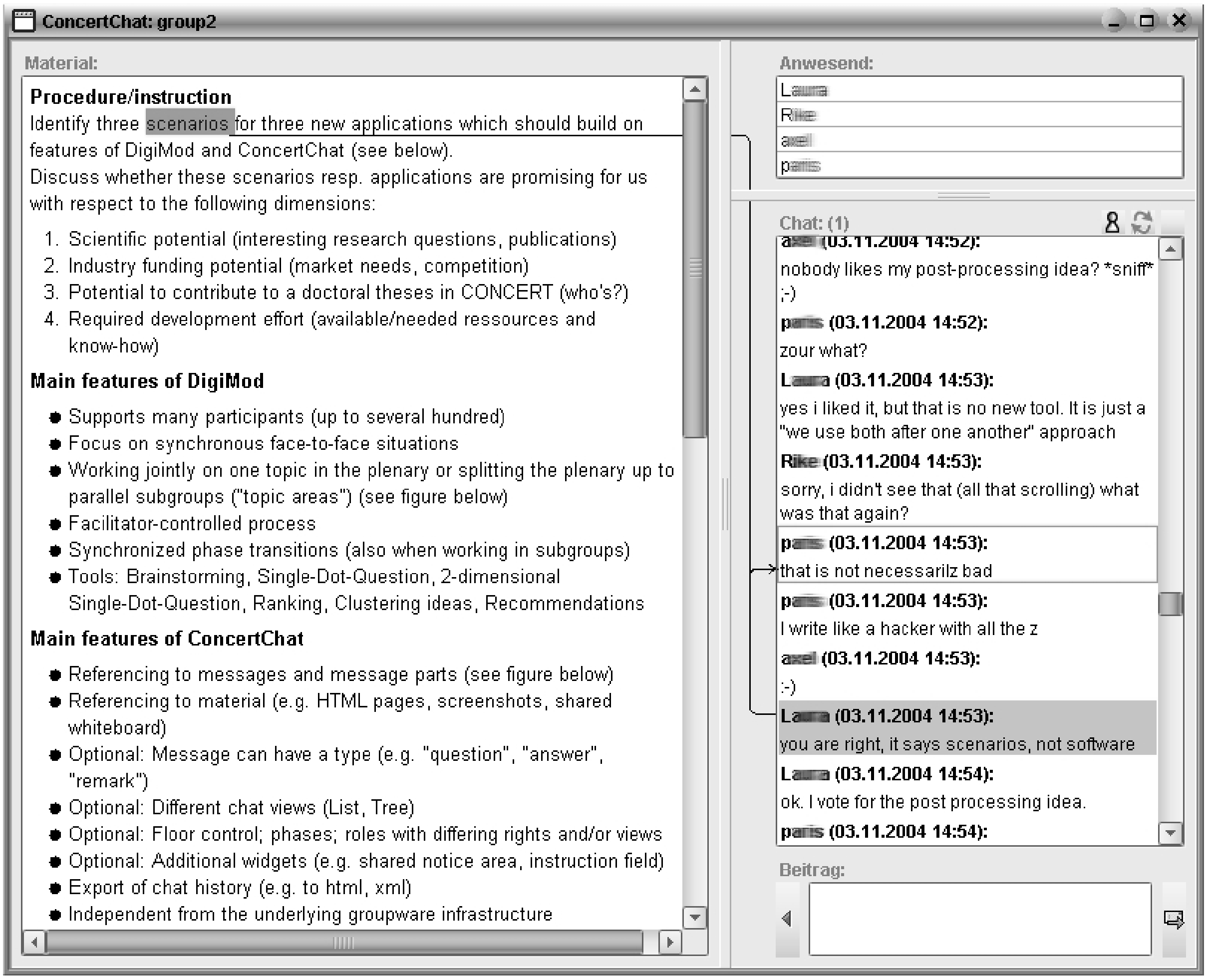

Figure 3: The chat tool for the case study. It shows the usage of multiple references for one contribution.

After a short introduction to the usage of the tool to be used for the chat, the group split up into 4 separated rooms each equipped with a networked computer running the chat tool. They filled out a questionnaire about their chat competency and their knowledge about the two projects, which build the basis of the task. Then they read the instructions and background material (1 page) in printed form. Following this, the group started to chat for 50 minutes. The page with the instructions and background material was included in the material area of the chat tool. Finally, the participants filled out a second questionnaire, gathered in one room and reflected on the session together with the authors of this paper.

Results

Chat competence and familiarity with the two projects that form the basis for the task is relatively high: Three participants chat on a daily basis. The fourth participant chats less than once a month. Three participants are involved in the DIGITAL MODERATION project and feel informed about the ConcertChat project. The fourth participant, a new member of the research group, has only minimal knowledge about both projects.

In order to learn more about the usage of the referencing functionality in everyday collaborative situations we analyzed the chat log. For 148 contributions out of the total 193, one or more references have been made to the material section or to other contributions. For 10 contributions more than one reference has been made (8 contributions had 2 references, 1 contribution had 3 references, and 1 contribution had 6 references). In more detail, there were 117 references indicating “response”, 20 deictic references to other contributions, 20 deictic references to the material, and 7 unclear or wrong references.

Contributions with multiple references combine responses, deictic references to other contributions and deictic references to the material in various ways: Combinations for double-reference contributions include 2 responses (1), 2 deictic references to contributions (1), 2 deictic references to the material (1), 1 response + 1 deictic reference to the material (3), 1 response + 1 unclear reference (1), and 1 deictic reference to the material + 1 unclear reference (1). The contribution with three references has 2 responses + 1 deictic reference to a contribution. Finally, the contribution with 6 references has 4 deictic references to contributions + 1 response + 1 unclear reference.

In addition to “repsonds-to” and the deictic use, we found three ways for using references that we didn’t expect:

- In twelve cases the reference was used to indicate that a previous contribution of the same participant is extended by the current contribution. In one case this connected three contributions, in all other cases it connected two contributions.
- In one case a reference was used as a kind of personal bookmark or pointer to another contribution that contained an explanation but was made 30 contributions before. The contribution contained the text “ah .. I put this here, to find my reference”.
- In one case (the contribution with six references) the references were used to respond and simultaneously collect four ideas generated previously in order to sum up.

The second questionnaire revealed that all participants regard the referencing to other contributions as helpful to improve the chat discourse. Two participants regard the referencing to material as helpful as well. All participants felt stimulated by the possibility to refer to other contributions.

DISCUSSION

The frequent usage of referencing shows that the functionality was accepted by the group. As expected, most of the references (117) indicated a “response” relation, but also 40 references were made to point to other contributions or to the material (20 references each). The participants used multiple relations in 10 cases. And there were unexpected usages of referencing – to connect split turns, to set a bookmark, and to sum up. Only 7 references were unclear or could be recognized as wrong. Altogether, this indicates that the participants quickly learned to use the referencing functionality in a variety of meaningful ways to support the chat discourse.

RELATED WORK

This section consists of two parts: First, we look at tools offering similar functionalities. In the second part we sum up related studies. The main functionalities of the chat tool we used in the studies above were:

- provide chat communication and shared material
- allow single or multiple references to other contributions and/or parts of the shared material.

Tools

From the tool design point of view, there are two principle approaches to ease chat communication: Providing references to other contributions (see Threaded Chat and Academic Talk below) and providing references to shared material (see Anchored Conversation and Kukakuka below).

Threaded Chat (Smith et al., 2000) is a chat tool that allows contributions to refer to one other contribution as a “reply-to”. The contributions are presented as a tree, which leads to significant problems, e.g. as new contributions are added to different, potentially distant, branches of the tree. To deal with this problem, our tool presented the contributions in chronological order and represented references as explicit arrows. Another path was taken by Academic Talk (McAlister et al., 2004). It provides two panes in the chat window. One pane presents contributions in chronological order, the other one presents the contributions in logical (tree) order as defined by reply-to relations. In both systems, Threaded Chat and Academic Talk, multiple references and shared material are not supported.

The Anchored Conversations tool (Churchhill et al., 2000) allows (normal) chats to be connected to a specific point in a related document. There is no support to refer from one contribution to another or to refer to different parts of the material simultaneously. Kukakuka (Suthers & Xu, 2002) couples threaded discussion and web pages. Multiple references to contributions and references to parts of the material are not possible.

The GraffiDis tool (Leponiemi, 2003) combines relations to texts and graphics. Users enter contributions (which can also consist of graphics and other material) at arbitrary places of the “chat” area. After a certain time the contributions are faded out to the background color. With a “history slider” the user can navigate through the discourse in chronological order. Relations between contributions are indicated by nearby positions in the chat area. References to a contribution are not possible after a certain distance in time as the previous contribution already faded out. Also, multiple references are difficult or even impossible if the contributions to be referred to are at distant positions.

To sum up, none of these approaches support references to contributions, references to shared material, and multiple references.

Studies

To the best of our knowledge, there is no previous study investigating the impact of explicit referencing in chat. But there are two categories of studies that help to interpret our findings. On the one hand, there are studies focusing on how variations of medial features influence the communication behavior and outcomes (McCarthy et al., 1993). McAlister et al. (2004) compare discussions in a normal chat tool with discussions in a tool that forces the participants to choose a sentence opener from a predefined fixed set and allows to explicitly define the reply relation. The discussions in that tool showed more on-topic messages and a higher quality of the argumentations than the discussions in the normal chat tool. Smith et al. (2000) found no differences in the task performance between groups using a normal chat and groups using a threaded chat, but a more balanced participation of fast and slow typists in the threaded chat. Čech et al. (2004) varied different aspects of the chat environment (e. g. size of message editor, availability of chat history) and showed that participants adopt their turn-taking and turn-packaging strategies.

Another relevant category of studies investigate chat usage for solving visual tasks. Suthers et al. (2003) compare face-to-face and chat interactions of dyads building a shared knowledge representation in a shared graphical tool. The study focuses on how the participants manage deictic references to elements of the graph representation. It is shown that the chat groups refer much less to the shared work space and in most cases to recently manipulated items. The authors conclude that online collaborators need better integration of information encountered over time and an easy insertion of visual references to the discussed elements.

Studies of chat use conducted in real world situations show, that experienced chat users discuss in more parallel threads (Isaacs et al., 2002), and that chat users can manage parallel threads when there are “observable contextual relations” (O'Neill & Martin, 2003).

CONCLUSIONS AND OPEN RESEARCH QUESTIONS

Referencing has a positive impact on chat conversations. We expect that this effect is increasing with a growing number of participants in the group as the risk of non-adjacent related turns increases with the number of participants. References are used to express a variety of conversational relations as well as to point to important objects in the chat log or in the shared material. We saw a tendency to focus on one reference per contribution to highlight the most important relation.

As was shown, referencing influences message production as well as message comprehension. This changes also the communication behavior of the participants, especially their strategies for grounding. Referencing as presented here exceeds models of threaded discussions in two dimensions: Messages can have multiple references and referencing can connect a message to other messages as well as to shared material. Thus, participants can use referencing to express a variety of relation types, not only a reply-to relation as in threaded discussion. By preserving the chronological order and using explicit references participants are still aware of all ongoing threads, which might lead to increased participation in parallel threads. Multiple references might even allow bringing together different threads. Further studies are needed to broaden the empirical basis for the interrelations described above.

In this paper we had only strictly synchronous chat scenarios, i.e. all participants attended the complete chat. It would be interesting to investigate whether referencing has a positive effect also in partly or completely asynchronous scenarios, e.g. supporting latecomers in their comprehension of the missed discussions or learners who use the (referenced) chat log as a learning resource after the discussion has ended.

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iTree: Does the Mobile Phone Encourage Learners to be More Involved in Collaborative Learning?

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Abstract. A web-based collaborative learning sites has the bulletin board system (BBS) and allow learners to interact, exchange information, engage in discussion, and collaborate on projects. This paper outlines the development and evaluation of iTree, a Java mobile phone application that encourages learners to participate in online BBS forums. In essence, the application reminds the students of their level of participation in a class BBS forum via an image on the wallpaper on their mobile phones. Postings to the forum are represented as a tree, the growth of which reflects the learner's degree of participation. Our evaluation has shown that iTree encourages learners to engaging in forum exchange in a positive light. Many learners have come to regard iTree as a useful learning tool..

Keywords: Mobile phone, e-learning, discussion, collaborative learning

RESEARCH BACKGROUND

Collaborative learning and e-learning

In recent years, higher education institutions around the world have expressed a growing interest in e-learning, or internet-based educational services (Tate 1997, Yoshida 2002, Kaneko 2002). The U.S has the highest ratio of e-learning with 90.4% of public universities and 55.9% of private universities now offering e-learning courses (Yoshida 2003). In Japan, the School of the Internet (SOI) at Keio University has been streaming video Web lessons since 1996 (Murai 2000). Since April 2002, a number of graduate schools have implemented e-learning programs, including Shinshu University and Tohoku University.- Background to this trend has been a progressive loosening of the accreditation criteria for distance education. This process was triggered by a 2000 University Council report that concluded "distance education, being of equal merit to face-to-face education, may now be recognized for up to 60 credits of a degree program" (The University Council 2000). The Central Council for Education also recently proposed that university courses "be made available off campus" (The Central Council for Education 2003). This trend toward looser university accreditation criteria is expected to continue. With it, university e-learning programs are also expected to spread.

iii online

Since April 2002 we have been developing and operating the e-learning site "iii online" for the Interfaculty Initiative in Information Studies at the Graduate School of Interdisciplinary Information Studies, University of Tokyo (Yamauchi, Nakahara 2002). Graduate students in the initiative can earn course credits by (1) watching on-demand lecture videos, (2) participating in BBS discussion, and (3) submitting final reports online.

Collaborative learning on BBS in e-learning site

BBS forums such as "iii online" are interactive communications tools that play an important role in web-based e-learning. Forums encourage collaborative-learning, information exchange, and discussion. However, many issues related to BBS use have yet to be addressed. One pressing concern the medium faces is learners need encouragement to browse and respond to BBS postings. Effective collaborative learning will not occur unless learners make an effort to read posts and respond to them. The situation is exacerbated when a learner does not keep up with the forum, when it becomes extremely difficult to catch up with the backlog of information and volumes of new posts .In order to address this issue, learners would benefit from a convenient system to inform them of BBS postings in a timely manner. Up until now, course coordinators, mentors, and moderators have had to take on this task (Salmon 2000; Collison, Elbaum, Haavind and Tinker 2000). Yet monitoring the board in this fashion often entails a very heavy workload (Nakahara, Maesako, and Nagaoka 2002).

To address this challenge, we have developed iTree, a mobile-phone application which encourages learners to participate in BBS forums. iTree displays wallpaper on a learners' mobile phone screens to keep them up to date with their level of forum participation and encourage them browse and post. Learners can simply glance at the screen in their pocket to check their level of participation and the level of board interest in their posts, saving a trip to the PC. We hope the convenience of the application will encourage the learner to browse and respond to BBS postings. iTree displays wallpaper images but has no posting or browsing function. Mobile phones have limited bandwidth, small screens, and often awkward text input functions and so we feel the PC remains more suitable for browsing or posting.

Educational use of mobile phones

Japan has a high rate of mobile phone ownership. As of May 2003, mobile phone penetration stood at 84.4 % (Including people in their sixties: 79.2%). Penetration rates among the young are especially high: 80.3% of teenagers, 96.9% of those in their twenties, and 96.2% of those in their thirties own mobile phones (Nomura Research Institute, Ltd. 2003). Because of this widespread penetration, many educators are optimistic about the potential of mobile phones as a learning tool. Some educators have even incorporated mobile phone technology into their course design. There are three categories of this kind of usage: Firstly, students have been sending course evaluations and comments via mobile phone. Otsuka and Yahiro have developed a class evaluation system that uses the mobile phone (Otsuka & Yahiro 2002) with students evaluating lessons by clicking through a checklist on their phones. One benefit is results can collected and tabulated instantly. The similar system was developed by Nakayama, Morimoto, Akahori, and Shimizu in 2001. Their system allows a lecturer to collect real-time feedback on his distance course via mobile phone. Secondly, mobile phones can now run language study materials such as drills and educational game applications (Seki, Shimizu, and Shigematsu 2001).

In addition, mobile phone subsidiaries now offer commercial education services geared in many fields, for instance courses in Engligh grammar and listening. Learner using the mobile phone can take a short quiz of English words, get the feedback when they make a mistake and memorize them(Fig.1 Copyright Marvelous Liveware Inc.&Sansai Books/Team Project Moetan). They can memorize English words over the mobile phone as they used CAI software on desktop computer.

Thirdly, schools now distribute to students official notices regarding class cancellations, scheduling changes, or job seminars via mobile phone (Yamaoka 2000). The e-learning mobile phone application we developed differs markedly from the above. We always have our mobiles with us, switched on and ready to use. When we make a call or check the time, the first think to catch our eye is the screen. We decided to take advantage of this prime real estate to encourage learners to participate in BBS forums.

The concept of WILD, or Wireless Internet Learning Devices, was introduced by Roschelle and Pea and billed as the future of collaborative-learning media. Roschelle and Pea also gave an overview of potential uses (Roschelle & Pea 2002). Examples of WILD given include (1) a response analyzer, (2) a database for field observations, (3) a sensor or measuring instrument, (4) an exhibition guide in a museum. Although the Internet-connected mobile phones such as those used in Japan can indeed be classified as a variety of WILD, Rochelle and Pea made no mention in their report of iTree-like applications for e-learning (Roschelle & Pea 2002).

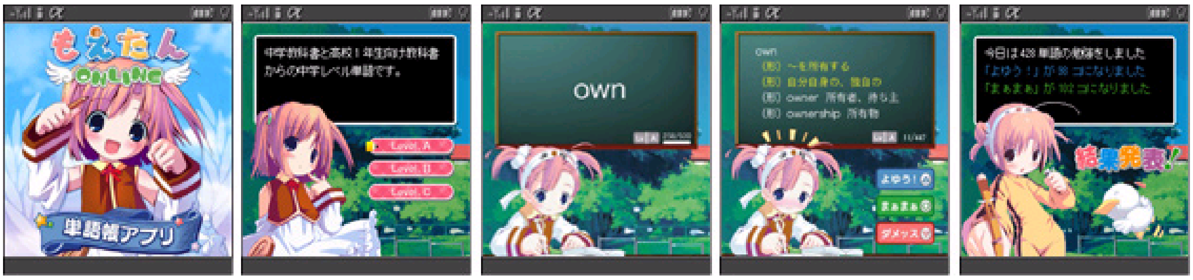

Fig.1. Commercial web site over the mobile phone to memorize the English word (http://www.moetan.jp/online.html)

ITREE

System configuration

iTree renews the wallpaper display with enrollment data stored on the "iii online" web server(Figure 2). "iii online" is housed on a Windows 2000 server running Internet Information Services (IIS) 5.0. The server uses the processing environment Active Server Pages 3.0 to handle iTree requests and various other functions. The iTree application runs on the Java SDK 1.4 development environment in NTT DoCoMo 504 Series mobile phones. Figure 1 shows a mobile phone with iTree installed. When a learner flips open his phone, iTree immediately retrieves updated data from the BBS server via HTTP protocol (Figure 3). First, iTree assigns each learner a unique ID with which it performs database searches. Results are sent to the learner's iTree via the HTTP protocol in text format. iTree then interprets this text data as a wallpaper image. It takes on average two seconds to load image data after open the lid.

The image is displayed as wallpaper on the LCD screen whenever the mobile phone is on.

The black arrow denotes this wallpaper. Switching on the power of the mobile automatically runs the iTree application, which refreshes the wallpaper image. The image begins to load as soon as the learner flips the mobile phone open. iTree immediately sends for and retrieves data from the BBS server via HTTP protocol.

Figure 2: iTree

VISUALIZING ON THE WALL PAPER

The choice of image needed to meet two requirements: (1) BBS forum information had to be available at a glance, and (2) the image itself had to be appealing. A tree which grows and changes was chosen to fulfill these requirements. The metaphor of a growing tree was chosen as (1) the tree itself comes to symbolize the learner and (2) the growth of the tree expresses growth in forum participation. The image of the tree is fixed in the middle of the mobile phone screen. The growth of the tree is affected by four variables: (1) your number of posts, (2) the number of times your posts are read, (3) the number of replies to your posts, and (4) your ratio of total forum posts to replies. These variable factors make up an individual user's BBS participation profile. Table 1 shows the screen changes that these variables correspond to.

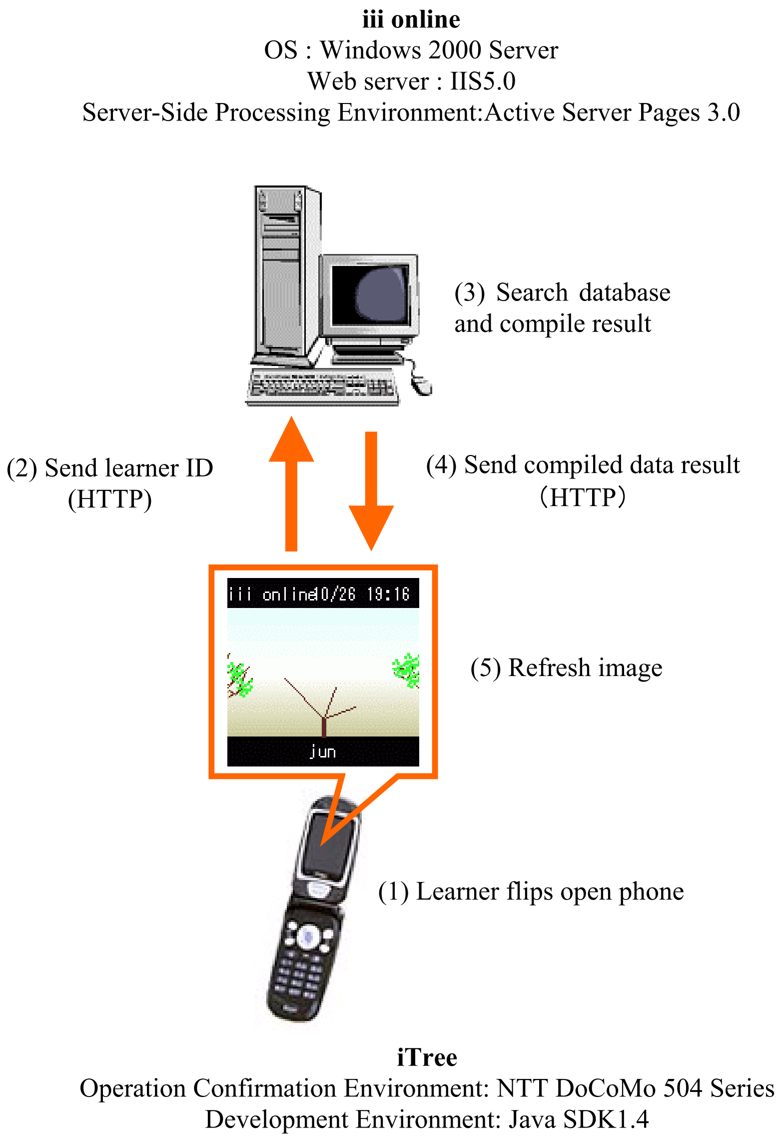

Figure 3: System Configulation

Table 1: Screen Changes

Participation Variable	Change on Screen
Number of posts	Tree growth. Posting thickens the trunk of the tree and grows branches on the
Number of times posts are read	Number and color of leaves. As posts are read, leaves sprout and turn green. After a certain period, leaves eventually fall.
Number of replies to posts	Red nuts. A red nut denotes a reply to a post.
Ratio of total forum posts to replies	Color of sky. The more replies received vs. overall posts, the darker the blue of the sky.

When a learner opens his mobile phone, iTree refreshes the screen image according to these four participation variables. In Figure 4, the number of posts is expressed as tree growth. Each post causes the tree to grow branches and the trunk of the tree to thicken. There are sixty-four stages to tree growth. When the final stage is reached, the tree covers the whole screen and growth stops. Conversely, if the learner neglects to post for a time, branches thin out and the trunk withers. In Figure 5, leaves indicate the number of posts read by forum members. The more forum members read a learner's posts, the thicker and greener his iTree leaves become. In Figure 6, the number of red nuts indicates the number of replies a learner's posts have attracted. One nut indicates one reply. Red nuts disappear in time.
The higher the ratio of a learner's posts with replies to overall posts, the bluer the iTree sky becomes, as shown in Figure 7. The rationale for including this factor is that a narrowing of this ratio indicates the learner is communicating interactively in the forum and therefore solving problems in a collaborative manner. Figure 8 indicates the screen changes that correspond to these four variables. Ordinarily, learners will see their own tree onscreen, yet with the touch of a button they can also view other learners' trees. Finally, of course there are other methods of encouraging learner participation in BBS discussions. The objective of this paper is not to explore this variety of possibilities, but rather to focus on a specific educational use of the mobile phone and analyze its effectiveness. The following section assesses the effectiveness of the iTree application when put to the test.

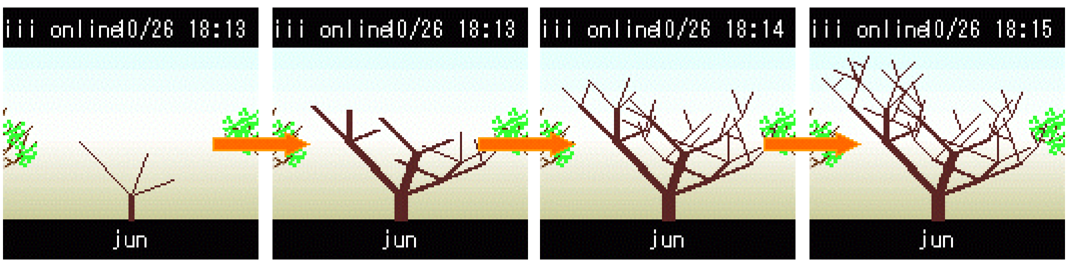

Figure4. the growth of tree's trunk

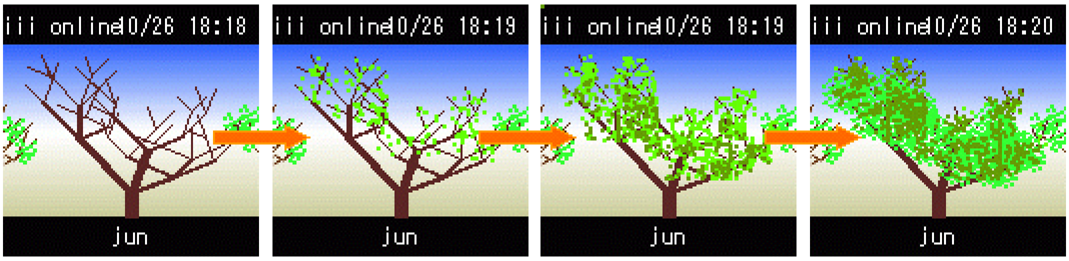

Figure5. the growth of tree's leave

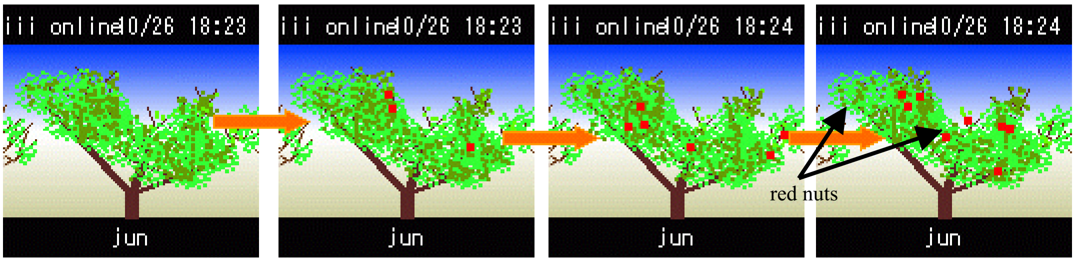

Figure6. red buts

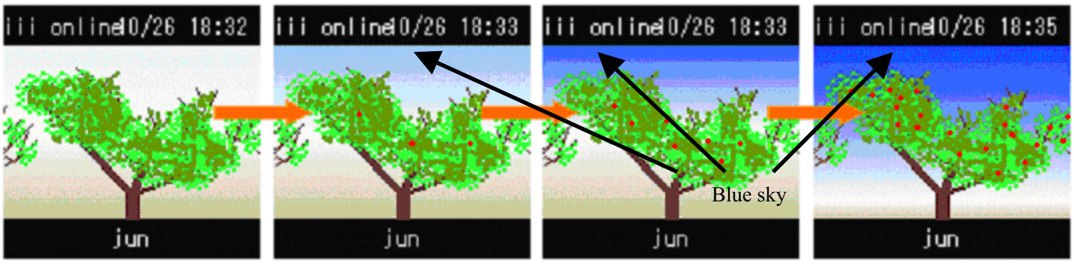

Figure7. The color of sky

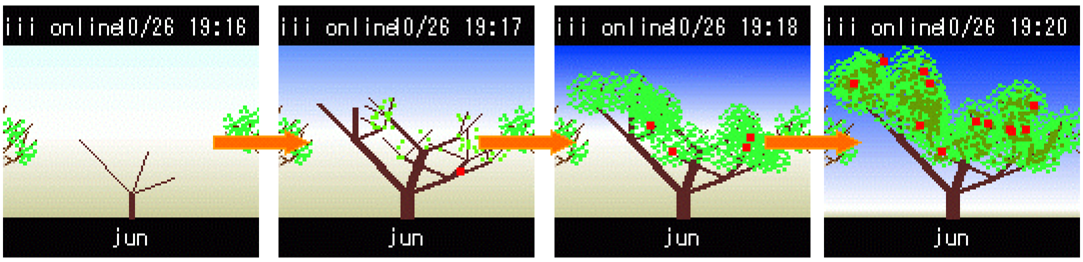

Figure8. The change of whole image

EVALUATION

Overview

Our iTree experiment was conducted in cooperation with students of information policy at the Interfaculty Initiative in Information Studies Graduate School at the University of Tokyo. The experiment was conducted on students in the course Information Policy, a winter term option of fifteen lectures given between Oct. 4, 2002 and Jan. 31, 2003. The first four lectures of the course summarized Japanese information policy at the national and municipal levels. In his fifth lecture, the lecturer asked students to research an aspect of information policy that took their interest and prepare a presentation on it for the class. The sixth to fifteenth lectures of the course consisted of these student presentations, which covered a wide range of subjects. Presentation titles included

“Transportation Policy in an Information Society,” “Remarks on Music and Money in TV Broadcasting,” “The Role of the Public Record Office in the Computerization of Public Administration,” “The Current State of the Contents Industry and Policy,” “Progress of Singapore IT Policy,” “Current Terrestrial Broadcasting and Public Broadcasting,” “Considerations on Mega-Disasters and Info-Communications”. Students were also asked to conduct Q&A sessions and discuss the presentations in the course BBS forum. The ten information policy students asked to volunteer as subjects of the experiment were asked to use iTree throughout the remainder of the course. At an early stage, one subject dropped out, leaving the experiment with nine subjects, four male and five female.

Vantage points and methods of evaluation

We set the following three vantage points: (1) Have the subjects been browsing the forum?, (2) Have the subjects been posting to the forum?, (3) How does the learner evaluate iTree?.
In order to answer these three questions, we analyzed the data in the following way: First, focusing on points (1) and (2), we analyzed "iii online" log data and compared the iTree group and non-iTree group results. The latter group numbered 53 students. To address point (3), the nine iTree group subjects filled out a questionnaire at the end of the experiment. eliciting responses on a five level scale: "Very much agree," "Somewhat agree," "Hard to say which," "Somewhat disagree," and "Very much disagree."

RESULTS

Effect of iTree on learner participation in a BBS forum

As previously mentioned, “participation” refers to browsing or posting messages in a BBS forum. Table 2 indicates the average numbers of times both iTree and non-iTree groups read and posted to the forum. On average, iTree group subjects browsed the forum 421.7778 times each (total number of browses: 3796; S.D.= 348.6734). On average, subjects in the non-iTree group browsed the forum 232.5849 times each (total number of browses: 12 327; S.D.= 242.5107). A Mann-Whitney’s U Test of the above result showed it to be statistically significant ($p<0.05$). On average, iTree group subjects posted 7.11111 times each to the board (total posts: 64; S.D.= 5.2546). Non-iTree group subjects on average posted 5.8235 times each (total posts: 313; S.D.= 6.9360). We did not obtain a statistically significant result for these figures. Consequently, our results indicate that iTree does not encourage learners to post. It does, however, encourage learners to read forum

Item (unit)	iTree Group (9)	Non-iTree Group (53)
Average number of reading sessions	421.7778(S.D.=348.6734)	232.5849(S.D.=242.5107) **
Average number of posts	7.111111(S.D.=5.2546)	5.8235(S.D.=6.9360)

** $p<0.05$

postings.

Table 2: Analysis of Log Data

Learners' subjective evaluations

The subjective evaluations of the iTree group regarding issues such as operation ease and appeal of images is shown in Table 3. Responses to statements (1) “iTree easy to learn” and (3) “Useful BBS tool” were on the whole positive. Subjects tended to disagree with statement (2) “Screen hard to read”. These responses suggest subjects regarded iTree favorably in general. We also asked subjects how they responded to the changes in their tree. We found subjects responded positively to statement (4) “Worried about growth of tree.” This concern was evident in the generally positive responses to both statement (5) “Change in color or number of leaves triggered posting or forum browsing” and (6) “Change in number of red nuts triggered posting or forum browsing”. This concern suggests that iTree may act as a trigger for subject participation in a BBS forum. Leaves change color when others read your posts. Red nuts appear when others post replies to you. What is significant in both of these cases is that the activities of others are changing your tree. It would seem that interest in the responses to your posts is a factor which triggers a poster to browse the forum.

Table 3: Learners' Subjective Evaluations

Item	Very much agree	Somewhat agree	Hard to say which	Somewhat disagree	Very much disagree
1. iTree easy to learn	3	5	1	0	0
2. Screen hard to read	0	0	2	4	3
3. Useful BBS tool	3	4	2	0	0
4. Cared about thegrowth of tree	4	3	2	0	0
5. Change in color or number of leaves triggered posting or forum browsing	0	7	1	1	0
6. Change in number of red nuts triggered posting or forum browsing	4	5	0	0	0
7.Branch growth triggered posting or forum browsing	0	5	2	2	0
8. Change in sky color triggered posting or forum browsing	0	0	4	4	1

CONCLUSIONS AND FUTURE ISSUES

iTree, the mobile phone application developed and evaluated in this research project, was designed to increase student participation in course-related BBS forums. The application aims to accomplish this by simply displaying their state of BBS participation via mobile phone wallpaper. Our evaluation led us to the following three conclusions:

(1) Learners who use iTree more actively browse.
(2) Overall, learners evaluate iTree positively.
(3) Among the iTree functions, those which represent others' evaluation of a learner's posts have the potential to encourage learners to browse the forum.

iTree gives learners the information about who sent reply and when they should go to the forum. Some previous research has showed that learners need not only to share their knowledge but also to get the awareness information about the status of interaction (Gutwin, Stark and Greenber 1995). The information that iTree offered is a type of awareness information which triggered browsing. When learner get the messages from others, they feel like checking it and feel confident that their messages are relevant and useful for others. By this, iTree motivated learner to participate in online discussion.
Nonetheless, there are still some issues yet to address. Most significantly, due to iTree's limited specifications, it does not sufficiently encourage students to post on forums. In the future, we may overhaul the iTree graphic interface in an effort to address this limitation. The number of higher education institutions offering e-learning classes grows every year. Applications such as iTree have the potential to facilitate this growth. This research marks the beginning of a mission to improve and refine iTree and related socially significant technologies.

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From CSCL Classroom to Real-World Settings through Project-Based Learning

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Abstract. A number of studies indicate that project-based learning enhances a student's motivation and in-depth understanding, while the CSCL environment promotes collaboration within the project. However, we know little about how teachers or curriculum designers should design a course utilizing the project-based learning approach according to real-world activities. In this study, we investigate an undergraduate cognitive science course that combines CSCL classroom activities with observational project activities in educational fields. As a result we identified three requirements of a project-based learning design to promote integration between classroom knowledge and authentic field activities: 1) Parallel-structured course involving both disciplinary and project activities; 2) Reality of the project activities; and 3) accessibility of the project content. In the conclusion, we discuss how these findings should guide the development of CSCL-based, project-oriented courses.

Keywords: Project-based learning, knowledge integration, teaching cognitive science

INTRODUCTION

Project-based learning (PBL) is a popular instructional method in classrooms all over the world. It is now generally accepted that projects play an important role in furthering the learning process. The importance of project activities that developed for a real-world purpose was pointed out in the first quarter of the last century (Kilpatrick, 1918). Many studies in the CSCL research field have discussed how to facilitate collaboration within the project. To ensure the pragmatic value of the knowledge integrated in the CSCL environment, we should also consider how to integrate classroom and real-world activities through PBL. Thus we seek to determine the design of a PBL course and the kinds of project settings that are suitable for students. This study describes the design of a concentrated elective course for undergraduates majoring in cognitive science. In this course, students engaged in class observational projects in educational fields based on knowledge-integration activities in their classroom, which were strongly supported by the CSCL environment.

DESIGNING PROJECTS

Although there have been many informative studies about PBL, most have been within the context of science classrooms. These studies indicate that projects promote a higher degree of engagement and inquiry (e.g., Linn & Hsi, 2000; Kolodner, et al., 2003). Because the fields of cognitive science are highly interdisciplinary and activity structures in the fields vary within their individual domains, we are attempting to identify a PBL design that will be able to integrate classroom knowledge with authentic field activities.

Three important elements of project design need to be considered. First is the timing of the project. In an interdisciplinary field, it is not practical to wait until the end of the course to conduct a consequential project. It would be more profitable for students to bring their questions from the field of the project back to the classroom, determine the disciplinary problem, and then proceed to the inquiry phase. Therefore, we propose a parallel-structured course composed of project and disciplinary activities. The second consideration is the project setting. The students should be able to apply disciplinary knowledge to the field based on a relevant understanding of the activity structure. Therefore, we are particularly concerned with the reality of the project. We believe facts observed in the field are useful in linking parallel activities and promote collaborative learning. It is important to observe the field carefully in the project activities. The third consideration is the content of the project, especially from the standpoint of its accessibility by the student. It is important that students be allowed to select and undertake projects based on their individual interests and ideas. We maintain that diverse, well-designed field activities and an appropriate level of content are important factors in achieving accessibility of the project.

Finally, in this study we decided to develop parallel-structured course that includes a variety of class-observation projects. We investigated whether the project activities in a parallel-structured course with high reality and accessibility would promote knowledge integration between classroom learning and field activities.

RESEARCH CONTEXT

Course Overview

A three-day concentrated elective course based on the CSCL environment began in 1998 (Miyake, et al., 2001). In a two-month course term, three classroom activity days are allocated between intervals. The course objective for the 2004 program was to "Observe and evaluate the class from the cognitive science point of view and make suggestions to improve the class." A total of twenty-five students attended the entire 2004 course. Every student had studied the basic concepts and findings of cognitive science in prior courses. Three teaching assistants (TAs) attended this course. The first author was a TA and the second author was a lecturer in this course.

To equip the students with a basic knowledge of the project, this course exploited several CSCL methods and tools. The students used video clippings and a commenting system called Commentable Movie Sheet (CMS). Through the CMS, they could review the streaming of resources and clip the important points out with their comments (Miyake & Shirouzu, 2004). They used a reflective note-sharing system called ReCoNote to summarize the essence of the resources for a jigsaw session. The jigsaw sessions, called complex jigsaw, were structured to guide effective interdisciplinary knowledge integration (Miyake, et al., 2001).

By the end of the 2003 program, the objective of the project activities in this course was to design and propose a class based on the findings of cognitive science. Even though students integrated the findings of cognitive science for the projects using the CSCL environment, their outputs indicated that it was difficult for them to connect class design elements and the findings of cognitive science (Masukawa, 2003). They tended to rely on their experience in the CSCL environment or try to impose their cognitive science knowledge on the design. We recognized that students did not sufficiently understand the activity structure in the field and did not have the opportunity to observe concrete facts to link the project with their classroom knowledge. Therefore, in the 2004 program, we rearranged the project and disciplinary activities and set the class observation in the first part of the parallel-structured course. In this way the students could bring their observed facts back from the field before proceeding to the disciplinary activities in the classroom to analyze the problem.

Table 1 Structured course activities (Activities are numbered from #1 to #21 in sequential order.)

	[Disciplinary Activities]			⇔ [Project Activities]
	Observe the class +	**Integrate cognitive science findings** ⇨	**Integrate class observation and cognitive science findings**	
Phase 1	#2. Think about Japanese science classes #3. Analyze the activity structure of Japanese science classes #6. Think about the best practices		#4. Link the positive points of the class to evidence from cognitive science **[A]** #7. Clarify the evidence of goodness of the class **[B]**	#1. Introduce the projects #5. Kick off the projects #8. Plan the field activities **[C]**
Interval 1				#9. Observe the class
Phase 2		#11. Integrate cognitive science pieces of work about human learning through the complex jigsaw	#12. Point out the important cognitive science findings to evaluate the class **[D]** #13. Organize cognitive science findings to evaluate the class **[E]**	**#10. Interim session** #14. Reanalyze the observed class **[F]** #15. Reflect and reorganize the project **[G]**
Interval 2				#16. Project activities
Phase 3			#17. Review the preliminary presentation ***Focus of analysis***	#18. Prepare for the final presentation **#19. Final session** #20. Reflect of the project #21. Plan the future work

Course Design and Projects

Next we describe how we implemented our three design requirements: parallel-structured course, reality of the project, and project accessibility. We allocated parallel disciplinary and project activities in a three-phased course structure, as shown in Table 1. We designated three substructures in disciplinary activities to undertake the project. The first aspect was class observation; the second involved the findings of cognitive science about human learning. In addition to these, we allocated a third to integrate the knowledge gained from both aspects. The students engaged in a total of twenty-one activities within this parallel structure.

The objectives of each phase were as follows. The objective of Phase 1 was to observe and evaluate the class. At the end of the class activities they made a plan of observation and observed the class in Interval 1. The objective of Phase 2 was to evaluate the class using evidence from the cognitive science point of view after the interim project report session. The objective of Phase 3 was to make suggestions to improve the class design. In the final session, students presented project reports that included class analysis, evaluations, and suggestions.

Each student participated with the disciplinary activities in the group other than the project group. After every activity, each student wrote personal ideas on the activity worksheet with brief prompts as scaffoldings. We supposed that the items on each sheet represented the student's knowledge-integration levels of disciplinary and project activities. We selected seven worksheets designated as A to G in Table 1, as well as the project reports in the interim and final sessions, to focus of our investigation of students' knowledge-integration activities.

As for the projects, diverse, well-designed educational settings were selected from lectures in school, classes in the Nagoya City Science Museum (NCSM), and exhibitions also in the NCSM. On the first day of the course, each student selected one project from eight alternatives, based on their interests. The kinds of field activities selected were up to each student, to respect their individual motivation and ideas. Finally seven projects were formed. In this study we focused on the following four projects that observed the class or exhibition in the NCSM. The Advanced Science Workshop (ASW) was an organized class of the NCSM for students at the high-school level and above. The aim of this workshop was to obtain a thorough understanding of physics through experiments and discussion. The Manufacturing Lab (ML) was a class for elementary and junior high school students at the laboratory corner in the NCSM. The students of the lab crafted a toy that was a paper plate attached to a motor. The vibration of the motor is transferred to the plate, and the miniatures on the plate begin to swing and turn. "Life on the Earth (LIFE)" is a regular exhibit in the NCSM. This corner shows how people adapt to the local climate. There are two adjacent glass-sided rooms called "heat room" and "cold room." Visitors can enter each room and experience the climate. "Let's touch a Tornado (TOR)" is another regular NCSM exhibit. Visitors can watch and experience the sensation of a tornado produced by a generator positioned in the center of the exhibit.

RESULTS

According to our "focus of analysis" depicted in Table 1, we analyzed 421 items on 140 worksheets. We selected 42 items from the reports of the interim session and 85 items from the final session. To evaluate the level of items, we used a single scale shown in Table 2, in accordance with the course objective. To address the transition of the level, we calculated the weighted average level of items using the points in Table 2. Inter-coder agreement rates between three independent coders were 85% to 90%. We were able to negotiate all discrepancies.

Transition of Item Level

Transition of the weighted average level of the worksheets demonstrated that the knowledge-integration level became higher in Phase 2 (A: 1.88, B: 2.20, C: 1.67, D: 2.71, E: 2.29, F: 2.34, and G: 2.26). The weighted average levels of both sessions (interim session 2.19, final session 3.01) demonstrated that the preceding activities in the parallel-structured course were relevant to these sessions. In the final session, there were 31 items at point level 4: 21 items were at L4, and 10 at S4 in the entire class.

Table 2 Integration level of items

Level	Description	Point
L0	Irrelevant words	0
L1	Keywords or phrases only	1
L2	Explanations of the class or exhibition	2
L3	Explanations from the cognitive science point of view	3
L4	Evaluations of the class or exhibition supported by cognitive science findings	4
S2	Ideas for improvement	2
S3	Preliminary suggestions for the class or exhibition	3
S4	Suggestions for the class or exhibition supported by cognitive science findings	4

Activity Process

We analyzed all worksheets to find in each project the first mention of the concepts that were clearly related to the final items. By the end of the interim session, 43 of the final 85 items (50.59%) were mentioned in a student's worksheet or project output in all levels. As for the level 4 items, 19 of the final 31 items (61.29%) were mentioned by the end of the interim session. These results indicate that level 4 items in the final session were raised in the early stage of each project, and the group improved on those items through parallel activities.

To investigate the activity process in detail, we organized all the items on the worksheets in relation to the final 85 items. Table 3 is one of the ML project activities. In this process, four members thought about the uses of a motor. In the ML class, the children made a toy using the vibration of a motor. However, project members wondered if that application of a motor was for turning rather than for vibrating. Table 3 shows that members wrote about the motor instruction with a variety of expressions, and they reconstructed their ideas. They also linked their observed facts to the findings of cognitive science that they had integrated in disciplinary activities. It is notable that Worksheets D and E were the disciplinary activity sheets, and each member of the ML project engaged in these disciplinary activities in a group other than the project group. In the final session they offered suggestions about instruction focusing on a motor, as the S4 item. Observed facts effectively promoted the students' collaborative learning process. Accordingly, two of our design requirements, parallel-structured course and reality of the project, successfully contributed to effective knowledge integration.

Class Design vs. Class Observation

In the equivalent three-phased 2003 course, students engaged in a class design project. It was a kind of imaginary project at the end of the course; that is, they hadn't conducted any field observations. Each project had a poster session in Phase 3; in this session each project group presented a detailed lecture plan and its advantages. It was expected that by presenting the advantages during the poster session, students would be able to demonstrate how they integrated the findings of cognitive science into their design. However, 16 of 30 advantage items (53.33%) were based on their existing classroom experiences (e.g., to utilize jigsaw session, group activity, or discussion board). These results from the 2003 study told us that a class design project did not provide concrete observable facts. For this reason, students tended to rely on their existing experiences in the CSCL classroom.

Characteristics of Projects

There were seven projects in this course. Each project group improved their output toward the final session, but there were differences among the project groups. To clarify the differences, we summarized the characteristics of the four NCSM projects in Table 4. As shown in Table 4, the starting levels of the project at the interim session and the number of the project members aren't directly related to the final levels. These differences come from two sources, the level of content and the profile of the field activities.

The final levels and the improvement of the ML and LIFE projects are high. It could be that the contents of the ML class and LIFE exhibition were at the appropriate level for each project. The improvement in these two projects suggests that students could have gained concrete facts through their observations and they had exploited the facts to promote their activities. Comparing the difference between the two projects of the NCSM exhibitions,

Table 3 Items on each worksheet about a motor in the ML project

Sheet	Student U	Student O	Student S	Student N
D	Did the teacher teach how can they use it in another context?	Teach the relation between this craft and subjects like math or science.		
E	Can they apply this to a more general problem?		Integrating knowledge that can be used in a broader area.	
F	The rule of vibration can be generalized later.	It was better to begin with thinking about the principle of a motor or making a motor.	Make the principle clear. That class was for lower grade of elementary school, so there wasn't a detailed explanation of the motor. Applying the motor to another context.	Did they understand the principle? Perhaps not. Did the teacher give enough information?
G			When we teach the principles to kids, what is the appropriate instruction level?	
Final	More general applications of a motor should be taught in the class. In that class, students engaged in crafts using a motor, but they knew little about how to use a motor. It is better to show how we can use a motor as a tool to do things. For example, it would be better to introduce another toy that uses a motor, so that they can see how it is used.			

Table 4 Comparison of the projects in the NCSM

Project	Interim	Final	Improve	Number of members	Class type	Content level	Field activities
ASW	2.00	2.75	0.75	4	Lecture	High	Observation with a video camera and interview with students and staff.
ML	2.17	3.75	1.58	4	Lecture	Medium	Observation with voice recorders and interview with volunteers.
LIFE	2.00	3.54	1.54	2	Exhibition	All	Observation of the corner and interview with various visitors.
TOR	2.17	2.53	0.37	4	Exhibition	All	Observation of the unit.

the profiles of their field activities were different from each other. The LIFE project engaged in a greater variety of activities than the TOR project. The output level of the TOR project improved, but to a lesser degree. This might indicate that the variability of the field activities of the LIFE project was one of the effective frameworks to evaluate the class. As for the ASW project, the members repeatedly mentioned the same concepts on their worksheets, but reconstruction and refinement of the idea were insufficient. The level of the content of the ASW classes was high; therefore project members may not have a sufficient understanding of the contents to apply the findings of cognitive science. In high-level content projects, there were many worksheet items that did not show up in the final session. It is possible that the students were unable to finish their evaluations.

From the comparison of the four projects, while it appears that the accessibility of the project primarily stems from the level of the content, it is also enhanced by the variety of activities undertaken by the students.

DISCUSSION

We investigated the connection between the CSCL classroom and real-world settings through PBL. The results positively indicate the parallel-structured PBL course, reality of the project, and accessibility of the content of the project are important to promote a successful linkage between classroom knowledge and real-world settings. The disciplinary activities of students in this study were strongly supported by the CSCL environment. Multimedia resources, technology for knowledge integration, and structured collaborative learning activities were the key factors in the students' progress. In addition to these, we pointed out three important design conditions to transfer classroom knowledge to the real world. Our three design requirements should be the key principles in the development of CSCL-based, project-oriented courses. It is particularly important to implement project activities that provide concrete observable facts in the CSCL environment.

Finally, we would like to address the question-and-answer sessions in the interim and final sessions. There were seven project groups in the classroom, and each group had its own field activities. The varied project settings corresponded to distributed expertise in the CSCL classroom. Discussions during the two sessions allowed the project groups to interact. Especially in the final session they brought up additional questions based on their own project and thoughts about future work through the interaction among the projects. Varied project settings may well be another design requirements in the CSCL environment to promote sustained inquiry.

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Collaborative Scaffolding in Synchronous Environment: Congruity and Antagonism of Tutor/Student Facilitation Acts

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Abstract. This paper focuses on the theoretical framework for investigating facilitation acts of the tutor and the students in problem-solving groups as reciprocally congruent. We propose to broaden the scaffolding debate in collaborative teams towards the areas of students' shared metacognitive and cognitive grounding acts. Similar tutor-supported and untutored science-related dilemma-solving activities in network-based synchronous mode were categorically analyzed and compared with respect to their scaffolding acts. We asked the question, whether there emerges the collaborative scaffolding situation in teams and how does tutor influence the peer scaffolding. Results indicated the presence of several scaffolding actors in collaborative teams. The nature of activity (tutored or untutored) had an influence on the practice of specific supportive acts by the tutor and the students. The various interrelations between student and tutor scaffolding acts must be considered when preparing the tutor support during problem solving.

Keywords: collaborative scaffolding, synchronous learning, supporting dilemma solving

INTRODUCTION

In this paper we explore the functioning of a variety of support systems, which occur during collaborative problem-solving activities in synchronous network-based settings. As a result of interpreting specific discourse acts in the frames of dialogue act theory (see Clark & Schaefer, 1989; Traum & Allen, 1994; Traum 2000), we suggest broadening the scaffolding metaphor in collaborative teams by conceptualizing student grounding and tutor facilitating acts as being reciprocally congruent. This new framework highlights collaborative scaffolding issues and enables the study of inter-relations of different-level scaffolding actors in teams.

Collaborative scaffolding situation

Two parallel approaches have been developed for understanding the support processes in teams – one has focused on students in symmetrical collaborative learning situation, whilst the other has concentrated on the tutor in asymmetrical groups. There are few studies, however, which combine these two approaches while interpreting the interactions in tutored collaborative learning situations.

The research in untutored problem-solving groups relates to peer support in both metacognitive and cognitive domains. These support-acts are seldom interpreted as scaffolding. Support in the metacognitive domain is usually viewed from three perspectives. The first is 'self-regulation', where students support themselves in teams (Lipponen, 2001); the second is 'team-level metacognition', which focuses on team-level metacognitive reasoning related to the task and interaction (Jermann, 2002); and the third is 'socially-mediated/socially shared metacognition', a reciprocal process of exploring each other's reasoning and viewpoints in order to create a shared understanding of the task (Goos, *et al.*, 2002; Iiskala, *et al.*, 2004). The support in cognitive domain is viewed as 'shared cognition' – the cognitive level grounding in order to construct shared knowledge (Dillenbourg & Traum, 1999). Rasmussen (2001) and Fernandez *et al.* (2001) assume, however, that whole communication can be viewed as the mutual and partly unconscious 'scaffolding', which invites participants to follow the implicit ground rules and develop and test their own constructions of meaning with others.

The research about promoting collaborative learning considers the influence of the more skilful and knowledgeable tutor or trained peer-tutor on students learning. In terms of facilitation there is a general trend to view the tutor as the coordinator and the students as the performers of the task-directed learning process. This conception of scaffolding has its roots in research about the relationships between the teacher and the learner in dyadic well-defined problem-solving situations. According the scaffolding metaphor defined by Wood *et al.*, (1976), an adult has to *'control those elements of the task that are initially beyond the child's capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence'*. Vygotsky (1978) has assumed that teacher creates the conditions for certain students' cognitive processes to develop, without directly implanting them in the child. He defined the idea about the Zone of Proximal Development (ZPD), which is *'the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers'* (Vygotsky, 1978, p.86). The more knowledgeable person was believed to influence students' cognitive processes in the range of their ZPD.

Transferred to the collaborative learning situations, the initial theory about the ZPD and the scaffolding metaphor could be developed further in order to explain the phenomena at the group level. Wells (1999) argued that ZPD applies potentially to all participants not simply to the less skilful or knowledgeable ones. In accordance with this, the ZPD concept was explained as the bi-directional teacher-learner and learner-learner ZPD (Forman, 1989; Goos *et al.*, 2002). Goos *et al.* (2002) describe the ZPD as the learning potential in small groups where students have incomplete but relatively equal expertise and where each partner who possesses some knowledge and skills requires the others' contribution in order to make progress. At the level of understanding thematic information in relation to certain task and learning goals, continuous grounding processes between the team members must take place (Veerman, 2000). These interpretations of mutual ZPD and scaffolding diminish the role of more knowledgeable tutor and open the possibility of viewing all the members in learning group as possible scaffolding actors.

We also posit a similar origin for the tutor's regulatory phenomena and the cognitive/metacognitive grounding acts, which take place between students in teams. If confirmed we can begin to think of a combined collaborative multi-actor scaffolding situation between the students themselves or the students and the tutor in teams.

Congruity of peer grounding and tutor scaffolding acts

The utterances of all the team-members are delivered as 'dialogue acts' during communication (Traum, 2000), regardless if there are only students or if a tutor is involved. Clark and Schaefer (1989) distinguish two types of individual acts: 'autonomous acts' are those that an agent performs on his or her own and 'participatory acts' are performed as parts of collective acts. The latter type of acts can be related not only to shared metacognition and cognition, but also to scaffolding.

Most of participatory acts begin with an action by A, the contributor. The process of contribution divides conceptually into two phases: i) 'presentation phase' when A presents utterance for B to consider and ii) 'acceptance phase' when B accepts utterance by giving evidence that he believes or understands what A means. In collaborative teams tutor and students can perform both phases of the participatory act. It is also clear that several actors may respond to any presentation phase act, and acceptance phase acts can serve as new initiators of participatory acts.

Luhmann (1992) distinguishes three concepts related to communication: information (something that is in the head of the actor), utterance (something what the actor spells out/writes) and understanding the difference between information and utterance (how the other actor interprets the information in utterance). The latter is dependent on the other actor's state of mind i.e. their intentions. Thus, effective communication in team depends on mutual understanding and grounding of each other's intentions during participatory acts.

As much of one's behavior arises from sense of obligation to behave within the limits set by the society that the agent is part of, Traum and Allen (1994), and Traum (2000) have proposed the communication model that is based on obligations and goals. Obligations represent what an agent should do, according to some sets of norms. When planning, an agent A considers both its goals and obligations in order to determine an action; when deciding what to do next, the obligations are considered first and the agent B decides how to update the intentional structure (add new goals or intentions) based on these obligations. Obligations might also lead directly to immediate action. If there are no obligations, then the agent B will consider its' intentions and perform any actions which can satisfy these intentions. If there are no intended conversational acts, the next thing the actor B considers is grounding. Generally, grounding is considered less urgent than acting, based on communicative intentions, although some grounding acts will be performed on the basis of obligations, which arise while interpreting prior utterances (Traum, 2000). According to these discourse rules, it is possible to propose that the hierarchical structure of participatory acts starts from actor B considering the perceived obligations and intentions proposed by actor A. The next step occurs when the clear intentions of actor B govern his discourse acts. Grounding is an option to negotiate the intentions and obligations between two actors.

Clark and Schaefer (1989) and Traum and Allen (1994) have listed several acceptance phase types between two actors: accept, take action, partial accept, adopt, request for, clarifying obligation/intention, displacement with another obligation/intention, reject, and repair obligation/intention. Applying the hierarchical order of discourse acts, these can be viewed as more or less dominating in the discourse, depending on the actor B understanding of his intentions during the activity. This general model can be used in explaining participatory acts between the students in team, as well as, between tutor and the students.

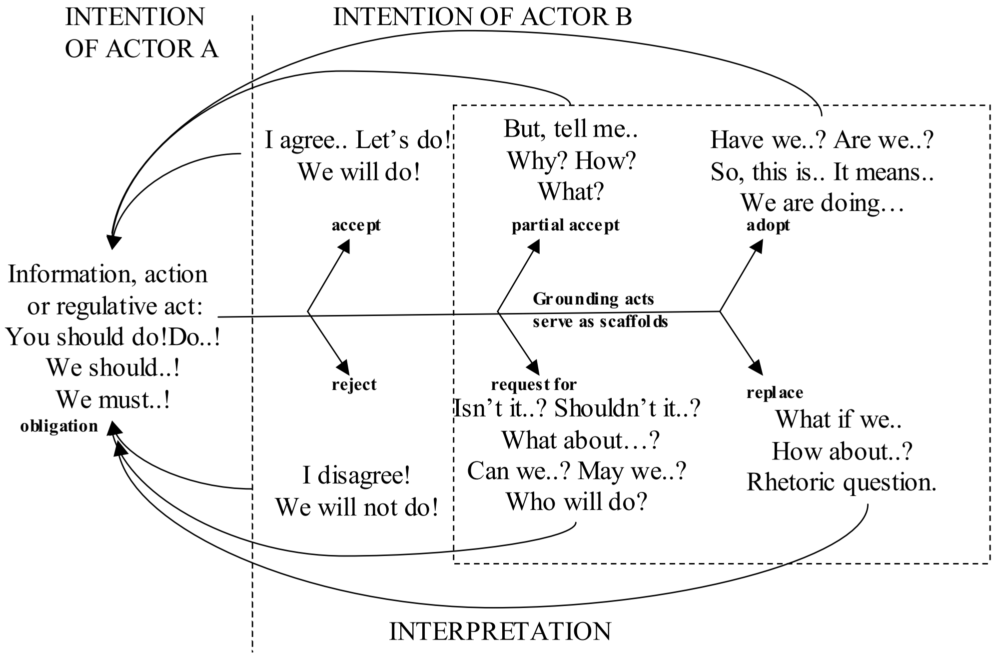

Figure 1. The flow diagram of discourse acts between the actors in non-tutored collaborative team.

Figure 1 presents a model of different level dialogue acts in collaborative team without tutor. The actor A has an intention to share some information or change something in the team by regulative act. It formulates an utterance that will be interpreted by any team-members (actor B) according to their intentions. Information can be agreed or rejected by actor B if it does/does not coincide with their intentions or if they do not have intentions of their own. This type of reply often terminates the discussion about this topic. Information or instruction can cause the teammates to initiate grounding if the intentions of actor A are not clear to them or if their intentions are different. These grounding acts may be of accepting type, when actor B agrees to actor A in general, but needs some more information (partial accept). Actor B may also reformulate the information/supposed-action-he-has-started-to-perform/instruction with its own words in order to control the coherence with the intentions of actor A (adopt). Grounding acts may also be of rejecting type if actor B feels that there is a confrontation with the intentions of actor A or if there is not enough information to perform any action (request for). Second type of rejecting act can be replacement of proposed information or instruction with its own (replace) that indicates to the difference between the intentions of actors A and B. Both the accepting and rejecting type of grounding acts can, in turn, initiate negotiation between the team-members. Thus, grounding acts in team serve like internal scaffolds, which help to establish common ground in cognitive and metacognitive domains and the collaborative scaffolding situation emerges. This interpretation is in coherence with the ideas about bi-directional ZPD (Forman, 1989; Goos *et al.*, 2002) and scaffolding as the form of communication (Rasmussen, 2001; Fernandez *et al.*, 2001).

The participatory acts in the discussion can be related with the scaffolding function (e.g. scaffolding interactions introduced by Graesser *et al.*, 1995; Chi *et al.*, 2001). Participatory support acts that involve instructional scaffolding serve as discourse 'oligations' with the purpose of setting rules, setting conditions, setting restrictions, terminating, accepting or rejecting students' action or information. Participatory support acts that do not involve obligations, but favor some type of activity can be interpreted as 'intentions'. These may be practiced to scaffold the students in cognitive, metacognitive, affective and functional areas in order to help them to finish the task. Many 'intentions' and 'obligations' serve as grounding acts.

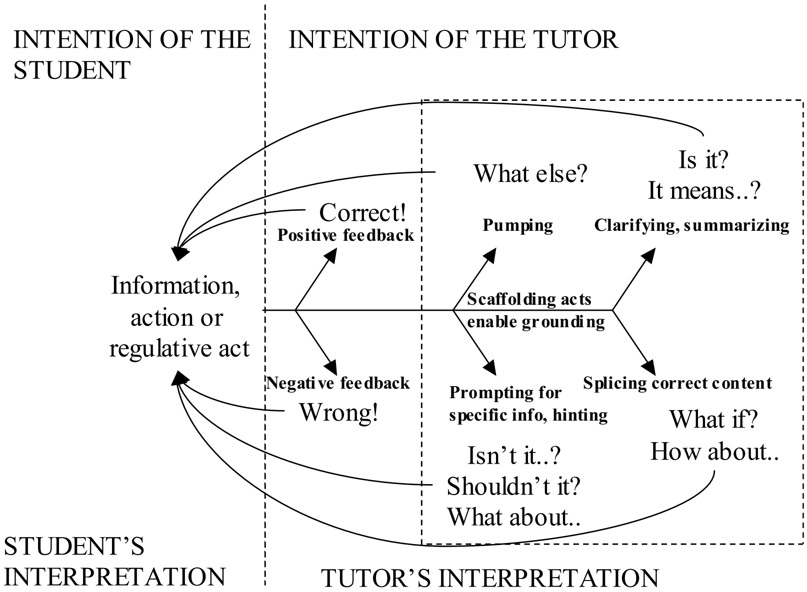

Figure 2. The flow diagram of scaffolding acts between the tutor and the student.
The scaffolding dialogue move categories by Graesser *et al*. (1995) have been adopted.

Figure 2 presents a model of dialogue acts in the collaborative team scaffolded by the tutor. In this model the tutor dialogue move categories, proposed by Graesser *et al*. (1995), have been used. If the student gives some information to the tutor or performs an action, the tutor interprets it in accordance with its own previous teaching intentions and the anticipated behavior of the student. The tutor scaffolding in response to student act can be direct accepting or rejecting (e.g. positive or negative feedback), partial accepting (e.g. pumping, clarifying, summarizing) or partial rejecting the information/action (e.g. prompting for specific information, hinting, splicing correct content). Student information or action may be agreed or rejected by the tutor if it does/does not coincide with its' teaching intentions. This type of support may be more common in coaching dialogues in which the tutor's aim is to support the student to reach the certain result.

In contrast to accepting/rejecting behavior, the tutor's task on scaffolding is not to coach the completion of the task but the student understanding how to conceptualize the task through the proper steps of action (Stone, 1998). In order to make scaffolding successful, the student's partial *'comprehension of the solution must precede production'* (Wood *et al.*, 1976) and the learner must have the *'ownership of the activity to be learned' (*Langer & Applebee, 1986; Järvelä, 1996). The student must be enforced to participate in active turn taking with the tutor (Palinscar & Brown, 1984; Järvelä, 1995) to evoke the internalization of new knowledge and skills. Elbers *et al.* (1992) support the idea that the basis for internalization is not the adult's situation definition, but the jointly elaborated situation definition of two actors. Thus, the tutor should use scaffolding acts that trigger students' grounding acts in metacognitive and cognitive domains. The partial accept type of scaffolds represent the tutor's intention to find coherence with students' intentions. When using the partial rejecting type of scaffolds the tutor is clinging to his own intentions that might decrease the students' active participation in joint elaboration of the task situation.

The comparison of certain types of student grounding and tutor scaffolding acts in teams indicate their similar purpose that can be related to the construction of the cognitive and metacognitive team coherence. The tutor has to identify the student understanding of the situation and the task, their perception of the tutor intentions, and their perception of themselves in the task framework. Besides the tutor, each student has to understand how their peers perceive the situation and the task, how they see themselves and the tutor in this situation, and what the intentions of the others might be. We may conclude that in the collaborative situations scaffolded by the tutor several scaffolding agents may exist simultaneously. The student grounding acts in teams can be theoretically interpreted as scaffolding acts, while the tutor scaffolding acts can be interpreted as grounding acts.

The inter-relations of student and tutor scaffolding acts

When planning the learning activities in synchronous environment it is important to know what type of facilitation patterns might be prevailing during the discourse between students in symmetrical learning situation and in the discourse where the tutor is involved. If we can show that scaffolding phenomena are part of common discussion practices among students working in team alone, the interpretation of the influence of tutor scaffolding in facilitated learning situations must be re-conceptualized. In order to assess the effectiveness of scaffolding in such situations it must be taken into account how the students might have performed on their own with self-scaffolding, how they performed with the tutor's support, and how the tutor's support might have influenced the usage of students' scaffolding acts.

Much more knowledge is needed in order to understand the influence of multi-actor scaffolding on team performance. It is open to question whether students and tutor are acting coherently in teams, considering the scaffolds applied by others (e.g. modeling or co-scaffolding), or does there emerge antagonism between two types of facilitating agents. The effectiveness of elaborating coherence between the tutor and the student scaffolding intentions in teams on students' problem solving and decision-making has been described in dyadic situation (Elbers *et al.*, 1992) and in collaborative teams (Pata *et al.*, in press). For effective regulating the group problem solving by tutor, it is of importance to investigate what types of tutor scaffolding acts can potentially inhibit or decrease the usage of specific student scaffolding acts common to untutored collaborative situations.

This paper aims to compare two similar cases of solving dilemma problems collaboratively in synchronous network-based environment in respect of the practice of specific types of scaffolding acts common to the tutor and the students. Firstly, in order to clarify, whether there is a reciprocal congruency between students' cognitive and metacognitive grounding and the tutor's scaffolding acts, we wish to discover, which types of scaffolding acts are common in untutored and tutored learning situations. The findings about the similarity of students' grounding and tutor's scaffolding acts should, in turn, enable us to consider the existence of multi-actor scaffolding situation in tutored learning teams. Secondly, in this paper we do not intend to compare the influence of these different level scaffolding actors' support acts on the team decision-making but to investigate whether the presence of the tutor might have influenced the usage of scaffolding acts by students. Thus three research questions were formulated:

i) Which support acts characterize the untutored and tutored collaborative dilemma-solving discussions in synchronous chat-rooms and is there a congruity of students' regulative grounding and tutor's scaffolding acts?

ii) Does there occur the collaborative scaffolding situation in tutored teams where several actors (tutor, students) perform mutual scaffolding?

iii) Is there a significant difference between the usage of students' scaffolding acts in collaborative untutored and tutored dilemma-solving activity which might suggest the emergence of concurrency and antagonism phenomena between the students' and tutor's scaffolding acts in the tutored situation?

METHODS

The data for this paper were collected from two separately designed experiments investigating decision-making in synchronous environments (Archee, 2004; Pata & Sarapuu, 2003; Pata, *et al.*, in press). During both studies students in synchronous network-based chat-room carried out the similar dilemma-solving discussions. In this paper we have reanalyzed the collected discussion transcripts from these two studies in respect of the practice of scaffolding acts. The activities were the following:

ACTIVITY 1. Dilemma solving without tutor in text-based mode (Archee, 2004).

Participants of the Activity 1 were 40 BA students of Communication aged 17-19. The task was to discuss in chat-room and to reach consensus upon the dilemma issue "Should it be law that HIV-AIDS positive carriers must disclose their medical condition to would-be employers, doctors, dentists, or even going for a driver's license?" Students were divided randomly into groups of 5-13 members who logged in to the network-based chat-room of Internet Relay Chat. They were not anonymous. Five decision-making discussions with total number of 1614 discourse acts were conducted with different students. The activity started with attributing the printed handout of the problem statement to the students. The activity lasted about 1 h and ended when the consensus was established from the viewpoint of the participants.

ACTIVITY 2. Dilemma solving with tutor in text-based mode (Pata & Sarapuu, 2003; Pata, *et al.*, in press).

Participants of the Activity 2 were 62 secondary level students aged 15-17, and 2 trained tutors. The task was to discuss in chat-room and to reach consensus upon the issue "What must be done with neglected dogs in cities?" The activity was designed as a role-play with jigsaw movement starting from making decisions in role-groups (Dog-owners, Dog-protectors, Citizens and Dog-asylum workers) and then negotiating these decisions in groups of experts (Councils of Town A and Town B) where the members from each role-group were at present. Five decision-making discussions with total number of 2077 discourse acts were conducted. In each role-play the students were initially divided randomly into four role-groups with the membership of 2-5 and during the activity they were redirected to the expert-groups with the membership of 4-7. In the beginning of the activity the students logged in to the certain virtual rooms of the network-based chat-room of Collaborative Virtual Workplace (CVW). The participants were anonymous, identifying themselves with certain names from the role-play (e.g. citizen1, citizen2). The activity started with attributing the web page with problem statement to the students. Verbal tutor support (instructions and prompts) and the web-based information about some important aspects of the problem for certain role-group (e.g. legislation about dogs, ethical considerations, economic calculations for dog-asylums) were also available in each virtual room. The role-play activity lasted about 1 h and ended when consensus was established by the expert-groups and they had composed the short decision document of the team.

The discourse in teams was recorded by the system and transcribed. On the basis of the theoretical framework introduced in this paper (see Fig. 1 and 2) the category-system was developed for investigating the scaffolding acts of the tutor and students. The seven types of scaffolds – *obligation, accept, partial accept, adopt, reject, request for*, and *replace* – were distinguished both in cognitive and metacognitive domains. Although possible, we did not categorize agreeing and disagreeing types of content-related responses under accept and reject categories of scaffolds because the intentions of these acts could be interpreted ambiguously. The examples of student and tutor scaffolding acts are presented in the Results part.

The frequency of different types of scaffolding acts was found both for students and tutor. The percentages of different scaffolding acts served as the basis of characterization of two activities. The Cross tabulation and the Chi square analysis were performed with student scaffolding acts in order to compare the usage of support acts in untutored and tutored situations.

RESULTS

We aimed to investigate, which types of scaffolding acts are used in cognitive and metacognitive domains by the students and the tutor in two activities. The category system was theoretically sustained by the idea that scaffolding and grounding acts in teams are used for similar purposes. The categories were developed according to the general intention types of dialogue acts. We considered all these discourse acts that were used to regulate the establishing of common ground between the intentions of the students and the tutor as scaffolding acts.

The following examples in Table 1 characterize different types of students' and tutor's scaffolds. The findings indicated that the student and tutor scaffolding acts were similar and differed from each other mainly in terms of the targets of the acts. The students directed the scaffolds most often towards themselves in teams, but also to some teammates or they left the responder open. The tutor was mainly directing the orders to the unspecified or to the concrete student, positioning himself outside the team. Moreover, in some cases tutor practiced scaffolding as an equal member of the team by using similar self-directed discourse acts like students.

Table 1. Examples of different types of tutor's and students' cognitive (C) and metacognitive (MC) scaffolds.

Discourse act categories		Peer's regulatory and grounding acts, which serve as scaffolds	Tutor's scaffolding acts that initiate grounding
Obligation	C	*We need to look at past cases to understand the implication involved in this topical discussion!*	*You, as animal protectors, must decide what to do to enhance the situation of neglected dogs.*
	MC	*We must find a better method to solve this problem!* *We must add corrections and make it better!* *We should make this picture better!* *To protector 6: Somebody should make the decision now!* *Choose the color! To protector 4: send us something to read, we want to discuss.*	*We should pay attention to the problem!* *Stay in your discussion room, you will meet other groups later on!* *Make the decision-document visible to everybody!*
Accept	C	*Let's discuss why people take themselves dogs without responsibility!*	*You can now discuss what the animal protectors think of this decision.*
	MC	*Let's just come to a decision and be finished with this!* *Ok Kathy, let's lead the discussion!* *To protector 4: we will decide!* *We will add the ideas in a minute.* *I will draw some line on the picture!*	*After you have read it, let's start discussing in the chat-room how to solve the problem.* *You can copy all the separate decisions into one to compound the decision of the animal protectors.* *If the leader has made the decision document we will make it visible to evaluate it.*
Partial accept	C	*What kind of laws??* *How can you infect others, when hospitals and other places are supposed to be clean?* *Why disclosed?*	*What bothers you the most in concerns of neglected dogs?* *How to control it?*
	MC	*Fine guys, what do you have to recommend then?* *What must we do with this model?*	*After reading the text the discussion will start – what must you do to solve the problem of neglected dogs?*
Adopt	C	*Okay, so have we agreed that aids should be disclosed in some circumstances i.e. medical and blood transfusions? So, is that our decision?*	*We have decided that dogs must be taken care of?* *Owner, do you agree that the dog owners are guilty in causing the problem and must take the responsibility?*
	MC	*Are we done then? Is our work ready?* *Do we have a consensus?* *Have we reached a consensus?* *We have reached a consensus.*	*Do you have consensus?* *Have you in principal agreed with the decision?*

Reject	C	*Hey, better if we will not start lecturing there.*	
	MC	*Don't' hurry!* *There is nobody from Tartu!* *The owner disagrees to be the leader!*	*Don't write dotted letters!* *You are wasting time, citizen7!*
Request for	C	*Are we going to talk about AIDS or what?* *But isn't it important in cases where there is a blood transfusion taking place?* *Janine, what about car accidents, the ambulance attendants need to know?* *Maybe not a badge, but how about some info on your license?* *Does anyone disagree, that such info should not be disclosed?*	*What do you think, are you satisfied with your decision from the point of view of animal protectors?* *Why the dogs are fierce – isn't it the fault of their owners?* *Should the neighbors take a look if the other people's dogs ok?* *Can all people take dogs?*
	MC	*Did you read the supplementary material?* *Have you read the supplementary material?* *Can we reach an agreement?*	*Are there any ideas how to make the decision draft better?* *Protector 6, is your decision getting ready?* *Could you write new ideas to your decision?*
Replace	C	*To protector 6: What if to organize the neighbors' guarding service?*	
	MC	*Protector 4, don't sleep, be active!* *Excuse me, Allison you should be concentrating on solving this problem, not talking to some guy in Kingswood!*	*Owner1 is in wrong room, he must be in another room!*

It appeared that during both activities the students and the tutor practiced various cognitive and metacognitive scaffolding acts. Thus, it can be assumed that in teams we must talk about collaborative scaffolding situation and consider the inter-relations of the student and the tutor scaffolds. Table 2 presents the frequency of different types of student and tutor facilitation acts in two activities. The usage of scaffolding turns among other types of discourse acts appeared to be more frequent (43 %) in tutored Activity 2 than it was in untutored Activity 1 (23 %). The significant difference ($X^2(3)=447.19$, $p<0.001$) between the activities was found in the usage of scaffolding act types. In untutored Activity 1 the usage of grounding type of scaffolds was noticeably higher and the cognitive scaffolds prevailed, whereas in tutored Activity 2 the '*obligation'* was the most frequent scaffolding act type and the majority of scaffolds were metacognitive. The higher level of instructional support in Activity 2 was partly explainable by the jigsaw design – the students worked in role- and expert-groups and had to move between different virtual rooms of the learning environment. Therefore some additional coordination of the activity was necessary by the tutor.

Table 2. The distribution of scaffolding acts in untutored and tutored dilemma-solving activities.

Scaffolding act types	Usage of scaffolding acts					
	Dilemma solving without tutor in chat-room		Dilemma solving with tutor in chat-room			
	students		students	tutor	students	tutor
	Metacognitive	Cognitive	Metacognitive		Cognitive	
Obligation	34 (9%)	7 (2%)	87 (10%)	238 (26%)	2 (<1%)	9 (1%)
Accept	31 (8%)	1 (<1%)	68 (8%)	21 (2%)	1 (<1%)	6 (<1%)
Partial accept	10 (3%)	102 (27%)	53 (6%)	7 (<1%)	43 (5%)	31 (3%)
Adopt	11 (3%)	25 (7%)	26 (3%)	10 (1%)	4 (<1%)	31 (3%)
Reject	0 (0%)	10 (3%)	9 (1%)	1 (<1%)	2 (<1%)	3 (<1%)
Request for	42 (11%)	79 (21%)	94 (10%)	52 (6%)	56 (6%)	39 (4%)
Replace	5 (<1%)	17 (5%)	1 (<1%)	2 (<1%)	7 (<1%)	0 (0%)
Total	374 (100 %)		903 (100 %)			

In this paper we were concerned, which types of regulative acts characterize the students who discuss dilemma without tutor. This type of activity could serve as an example of natural regulation processes in teams. We found that the most common metacognitive scaffolding acts used by students were *'requests for'* prompting specific information or action (*Can we reach agreement? Who will make the decision?*), directive and accepting type of orders (*We must...! We should…! Let's discuss..!*) from the *'obligations'* category. The most frequent cognitive scaffolds were pumping for info, which comprised *'partial acceptance'* of earlier info (*But how can you infect others if hospitals are supposed to be clean?*), *'request for'* additional info, which included the partial rejecting of earlier info (*Maybe not badge, but how about some info on the license?*) and *'adopt'* type of facilitation acts for clarifying or summarizing the situation (*Ok, so we have agreed that AIDS should be disclosed in some circumstances? So is that our decision?*). In the tutored situation the students' metacognitive scaffolding was persistent with same frequency, besides which the tutor practiced frequently the *'obligation' (Leader, you must make corrections in the note according to your team-members' decisions!)*, *'accept'* (*You can copy all the separate decisions into one to compound the decision of the animal protectors!)* and *'request for'* (*To protector4: send us something to read, we want to discuss!)* type of scaffolds, increasing the level of metacognitive scaffolding in teams. The practicing of cognitive type of scaffolds did not follow the same pattern. In tutored activity both the students and the tutor practiced less cognitive scaffolds compared with the untutored situation.

In order to investigate how tutor may influence the natural team performance the usage of student scaffolding acts during solving dilemma problems in untutored and tutored activity was compared by Chi square analysis (see Table 3). It was clear, that the design of the study did not enable us to make direct inferences about the tutor's influence on the usage of students' scaffolding acts in Activity 2. Yet, the similar nature of Activities 1 and 2 enabled of making predictions about the difference of the collaborative process of solving the dilemmas with or without the presence of several scaffolding actors. It was found that, in the tutored activity the student metacognitive scaffolds (*partial accept*) were used with significantly higher frequency ($p<0.001$) than in untutored situation. The opposite trend was common in untutored activity where students' cognitive scaffolding acts (*adopt, request for)* occurred with significantly higher frequency ($p<0.001$) than in tutored activity. It cannot be assumed, however, that if there was no tutor in Activity 2, the dilemma-discussions were performed more effectively. Among the investigated cases very different patterns of practicing the scaffolding acts were observed. Some tutored groups might not have been working effectively if there was no scaffolding by the tutor (see Pata *et al.*, in press). In some untutored teams, on the other hand, the problems occurred with focusing on the task, and the students might have needed additional external support (see Archee, 2004).

Table 3. The results of the Cross tabulation and the Chi square analysis of student scaffolding acts in untutored and tutored dilemma solving activities.

Scaffolding act types	Count of students' scaffolding acts (Std. Residual)				Chi square (df)	p
	Untutored situation	Tutored situation	Untutored situation	Tutored situation		
	Metacognitive		Cognitive			
Obligation	34 (-0.7)	87(0.5)	7 (2.5)	2 (-1.7)	9.57 (1)	0.002
Accept	31 (0.1)	68 (0)	1 (0.5)	1 (-0.3)	0.316 (1)	0.57
Partial accept	10 (-4.1)	53 (4.4)	102 (2.7)	43 (-2.9)	52.43 (1)	0.001
Adopt	11 (-2.0)	26 (2.2)	25 (2.3)	4 (-2.5)	20.91 (1)	0.001
Reject	0 (-2.1)	9 (2.0)	10 (1.8)	2 (-1.7)	14.31 (1)	0.001
Request for	42 (-2.4)	94 (2.2)	79 (2.4)	56 (-2.2)	20.93 (1)	0.001
Replace	5 (0.3)	1 (-0.5)	17 (-0.1)	7 (0.2)	0.38 (1)	0.53

The significant differences in the usage of peer's scaffolding acts in the tutored situation compared with the untutored one, as well as, the tutor's high practicing of metacognitive and low usage of cognitive scaffolding acts enabled to question, whether there occurred concurrency or antagonism phenomena between student and tutor scaffolding acts in Activity 2. The tutor's most common scaffolding act type was metacognitive instruction (*obligation*). It was not clear, however, how effective the extended usage of *'obligation'* acts by the tutor was during the Activity 2, because the students performed this type of scaffolding same often as in untutored Activity 1. We propose that the concurrency processes like i) tutor's modeling of the instructional behavior for students, and i) tutor's self-elaboration of his own scaffolding intentions in order to meet better the students intentions in team, as well as, antagonistic trends like iii) tutor's reformulation of students' metacognitive scaffolds according to his own intentions, or iv) tutor's acting regardless of students' scaffolding could take place.

Theoretically, in Activity 2 tutor's main aim should have been facilitating the student cognitive scaffolding acts what might have favored students to establish common ground on the dilemma solutions. In accordance with these suppositions, it was found that the student cognitive types of scaffolds were more frequent than those of the tutor in Activity 2. So we can think of some cognitive modeling processes taking place in the area of this type of scaffolds and assume that the tutor might have been considering flexibly the scaffolding acts performed by the students. On the other hand, in Activity 2 the student cognitive type scaffolds were used less frequently than in Activity 1. The cognitive type of *adopt* function (e.g. *You have now decided...*) was performed extensively mainly by the tutor in Activity 2, which might have inhibited the students from attempting clarification or summarizing of their discussion results that was common in untutored Activity 1. It may be that the presence of certain tutor scaffolds might have decreased the student responsibility for scaffolding their own cognitive functions and that antagonism between scaffolding actors played a significant role.

DISCUSSION

Supported by the dialogue act theories (Clark & Scheafer, 1989; Traum & Allen, 1994; Traum, 2000), in this paper we developed a theoretical framework for interpreting student grounding and tutor scaffolding acts in groups as reciprocally congruent. We focused on some scaffolding-related phenomena that influence learning in collaborative dilemma-solving teams. These were: i) The congruity of student grounding acts and the tutor scaffolding acts; ii) The emergence of collaborative scaffolding situation in teams due to several actors performing mutual scaffolding; and the necessity to re-conceptualize the interpretation of tutor's influence on peer scaffolding; and iii) The inter-relations of student and tutor scaffolding acts in teams and the possible concurrency and antagonism between them.

In our study two similar science-related dilemma-solving learning activities in synchronous network-based environments were investigated in order to illustrate the closeness of tutor and student facilitation acts with concrete examples. We did not design these learning activities as parts of one study, thus the learning situations are not comparable in all characteristics. Our aim was not to evaluate the direct effects of the tutor's presence on student performance, but to investigate if the untutored situation is comparable to the tutored context with respect to the usage of scaffolding acts. We could find a close resemblance of facilitation acts of the students and the tutor and suggest that grounding acts serve as scaffolds and vice-versa that scaffolding acts can be interpreted as grounding acts. Nevertheless, the data from these two cases did not allow us to generalize about the congruity of grounding and scaffolding acts in other types of collaborative learning situations. It is possible that the proposed framework need to be elaborated and concretized in order to describe all the scaffold types that are used in well-structured problem-solving situations and in teams, which deal with cognitive tools used in the construction of learning artifacts. We assume that some new types of scaffolds may also be found as a result of different cultural and community practices.

It is necessary to develop a new understanding of multi-actor scaffolding for collaborative situations. We assume that for predicting and influencing the regulation and grounding processes of different types of problem-solving teams, our theoretical framework of categorizing tutor's and students' scaffolding acts might serve as a useful protocol. In order to explain the learning and scaffolding situation in teams, three types of roles should be considered: the tutor as scaffolding actor, the student as scaffolding actor, and the student as task performer. They differ from each other in the consciousness of their intentions related to the performance of the task. When interpreting the teacher-supported collaborative learning activity, we should not focus only on the teacher's intentions and scaffolding aims. Moreover, from the perspective of constructivist theory, the role of the teacher as a scaffolding agent should be to favor the learners and move them towards the elaboration of task-regulation in this learning situation.

The comparison of tutored dilemma-solving situation with "natural" untutored activity indicated that in addition to thinking about tutor modeling and scaffolding processes, we should consider that some acts of student scaffolding might not originate from external tutor intervention but rather belong to the general communication phenomena like grounding. The lower frequency of student cognitive scaffolds in tutored teams compared with untutored situation might indicate that even the presence of the teacher can decrease or inhibit learners' natural facilitation processes. The frequency analysis, performed with two similar dilemma-solving cases, left open many questions about how to explain the different distribution of scaffolding acts. Could the tutor trigger some student scaffolding acts by modeling? Did the tutor scaffolds help students to elaborate tutor instructions and prompts according to their own intentions and thus enabled them to leadership roles? Were the tutor and the students using scaffolds regardless of each other? In further studies of collaborative scaffolding phenomena in both synchronous network-based and face-to-face contexts, sequencing analysis approaches might provide a better alternative, since the various tutor and student scaffolding interaction types can be more easily related to student learning variables. Secondly, the findings of the usage of specific scaffolding acts for different learning cases (e.g. well- or ill-structured problems, or use of verbal or visual artifacts) might enable the prediction of which inter-relations the tutor should emphasize in order to enhance learning.

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Assessment of Collaboration in Online Courses

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Abstract. New educational dynamics require new assessment strategies. In this article, three strategies for evaluating the collaboration of learners are presented and discussed: assessment of participation in conferences, assessment of competence and collaborative assessment. These strategies have been investigated in a course taught entirely at distance by the AulaNet, which supplies some mechanisms for the application of these new assessment strategies.

Keywords: Assessment, Collaboration, Distance Education

1. INTRODUCTION

Many online courses use the Internet in the instructionism approach: some content is made available for subsequent checking, through tests; of how much the learners have assimilated. Most Learning Management System (LMS) make available mechanisms for preparing tests; if all of the questions are multiple choices, then the environment itself can issue a grade the moment a learner finishes an exam. However, this assessment strategy is insufficient for an online course that makes use of a collaborative learning approach, representing a pseudo-innovation that optimizes the traditional practices.

In collaborative learning, each learner is responsible for his or her own learning and the learning of the other members of the group. If the learner and the group are responsible for the learning, then grading must also be carried out in a collaborative manner and no longer only by the teacher. In this article, the assessment strategies that have been investigated during an online course with a collaborative learning approach are discussed. The AulaNet and the course are presented in Section 2. Then, in Sections 3, 4 and 5 the strategies investigated in the course are presented: assessment of participation, assessment of competence and collaborative assessment. The conclusion is presented in Section 6.

2. COLLABORATIVE LEARNING AND ASSESSMENT IN AULANET

AulaNet is a Learning Management System based upon a groupware approach for teaching-learning in the Web that has been under development since June 1997 by the Software Engineering Laboratory (LES) of the Catholic University of Rio de Janeiro (PUC-Rio). The AulaNet is a freeware available in Portuguese, English and Spanish versions at http://groupware.les.inf.puc-rio.br and http://www.eduweb.com.br. Regarding assessment, AulaNet offers the Exams service through which the teacher prepares tests for the learners. For a more innovative assessment, the AulaNet offers services for Participation Follow-up and Competence Management, discussed in the next sections.

The AulaNet development team also develops and maintains the Information Technology Applied to Education course, ITAE (Fuks, Gerosa & Lucena, 2002), a discipline offered by the Computer Science Department which has been taught entirely online since 1998.2 (second semester of 1998.) The course offers a real environment for conducting investigations and experiments related to the development of AulaNet. The ITAE course is organized into two stages. In the first stage, learners study and discuss the course's subjects through seminars and debates, and the participation of learners in these discussion activities is evaluated (Section 3). In the second stage learners are organized into small groups based upon their competences (Section 4) in order to build new content for the course. Collaborative assessment is used to appraise the content developed by the group (Section 5). The final grade of a learner enrolled in the ITAE course is calculated as being the weighted average of the grades received for his or her participation in the seminars and debates and the grade given to the final version of the content developed by the group.

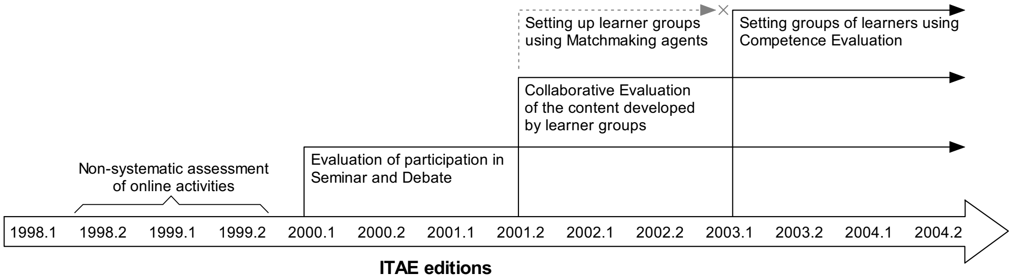

Figure 1. Assessment strategies tried out in different ITAE editions

The assessment strategies discussed in this article are the result of 7 years of experiments in the ITAE course. Figure 1 presents the chronological sequence of experiments involving these strategies in the course. In the following sections, we will discuss how these strategies were applied in the most recent edition of the course (ITAE 2004.2) and present the conclusions.

3. PARTICIPATION ASSESSMENT

One course subject is studied and discussed each week during the first phase of the ITAE course. Learners participate in an asynchronous seminar conducted through the Conferences service where specific questions are discussed about the topic being studied. They also participate in a synchronous one-hour-long debate through the Debate service. In this Section, we present the strategy developed for evaluating the participation of the learners in these discussion activities that take place in the ITAE course.

In a fruitful discussion, everybody is supposed to make significant contributions and send a similar amount of messages (Koyle & Aakhus, 2002). Anybody who participates without being prepared is cheating and disappointing the group. Anyone who merely reads the messages in a conference is not participating, only attending. When one person participates much more actively than the others, s/he is monopolizing the discussion. Thus, in order to evaluate the participation of learners in a conference, it is appropriate to take into account both the quality of their messages and the frequency of their participation (Fuks, Cunha, Gerosa & Lucena, 2003).

The strategy developed to evaluate the participation in the ITAE course is by multiplying the quality-grade by the quantity-weight of the messages sent by each learner during each seminar or debate session. The mediator evaluates the quality of the message by analyzing the text. The mediator gives each message a grade and, then, the average of the grades of the messages sent by a learner in a session is multiplied by the quantity-weight of messages s/he sent. Figure 3 shows some weighting models based upon the quantity of messages.

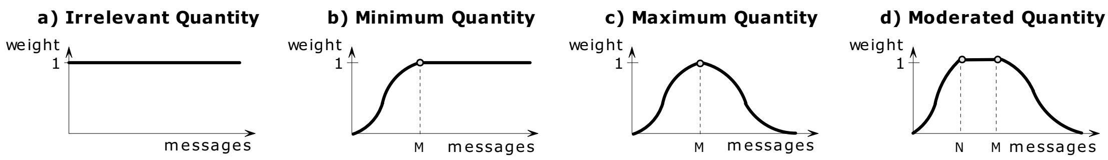

Figure 2. Models for weighing quality based upon quantity

The purpose of this assessment strategy is to get learners to try to achieve balance between the quality and the number of the messages they sent during the course's discussion activities. The next subsections show how this assessment strategy has been applied during the ITAE course seminars and debates.

3.1 Assessment of Seminar Participation

In each ITAE course seminar, one learner is selected to play the role of the seminar leader. This learner prepares the seminar text and three questions for group discussion. Learners then discuss the questions, arguing and counter-arguing based upon the messages that are sent by the learners. Mediators evaluate the messages as they are sent in over the course of the seminar, assigning a grade and writing a comment on each message. To evaluate the quality of a message sent during a seminar, the mediator analyzes the message based upon some pre-defined criteria. For each message, the mediator lists the main problems identified for each criterion. Based upon the quantity and the type of problems found, the mediator scores each criterion and gives the message a final grade. The average of the grades of each learner's messages is weighed based upon the number of messages s/he has sent during the seminar. The weighing function follows the Moderated Quantity model and was established that a learner must send from four to six messages per seminar (in this specific case of ITAE).

The seminar dynamics and the strategy for evaluating learner participation have been developed and tested over the ITAE editions. Figure 4 shows the average number of messages sent per learner per seminar, indicating the influences of the dynamics and of the assessment procedures that caused learner participation to improve and become more frequent.

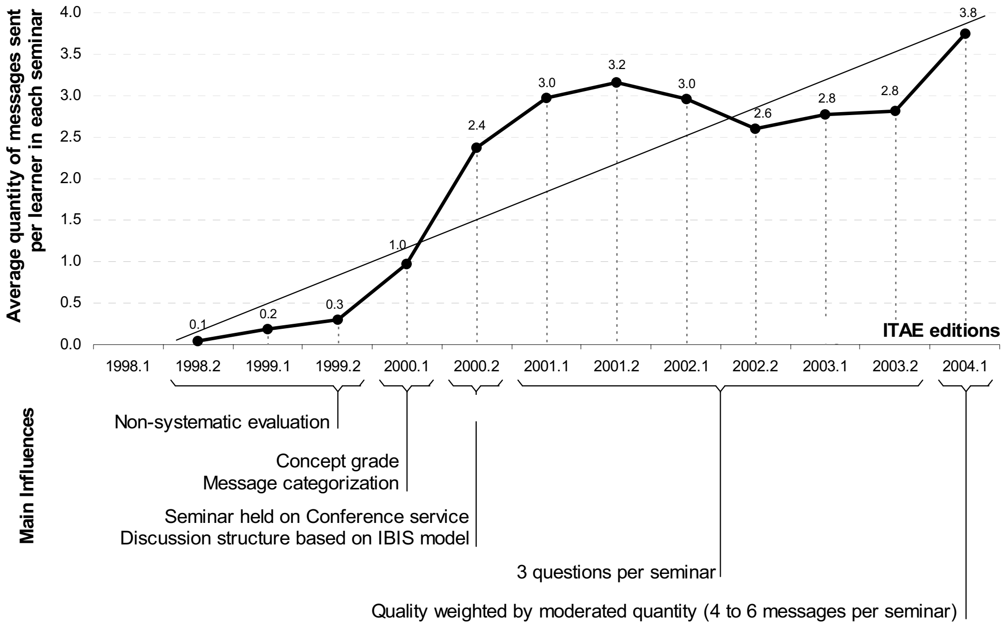

Figure 3. Average quantity of messages sent by learners per seminar

The 1998.1 ITAE edition was conducted in a 'face-to-face' classroom, and there is no data regarding learners' participation. Participation was sporadic in the 1998.2 to 1999.2 editions: on average, each learner sent only one message every four seminars. This fact mainly was a result of the lack of systematic assessment of participation. On the other hand, in the 2000.1 edition, seminar participation became more regular: on average, each learner sent one message per seminar. This regularity was due mainly to the messages being graded. In the following edition, 2000.2, the average quantity per learner increased, mainly as a result of the transfer of the seminars to the Conferences service (they previously had been conducted through the Discussion List service), where messages could be threaded. The discussion structure was based on the IBIS model (Gerosa, Fuks & Lucena, 2001). In the subsequent editions, from 2001.1 through 2003.2, the average increased mainly because it was defined that three questions would be discussed during each seminar. In the 2004.1 edition, it was established that each learner had to send between four to six messages per seminar (weighting quality by quantity), leading the learners to suppose that it was necessary and sufficient to send the lower limit of this target: they sent approximately four messages per seminar.

The main lesson learned from these experiments is that evaluating learners' messages, even simply by grading them, fosters participation and increases message quality. But it is not sufficient to simply grade the messages in order to properly provide learners with guidance. Commenting on the assessment is also necessary: it is desirable to follow a set of criteria to guide the assessment, but it is not feasible to present very detailed analyses about each criterion. Another important lesson is that multiplying quality by quantity of messages encourages submission of more messages without a concomitant decline in quality and makes the number of messages sent by learners more homogeneous.

3.2 Assessment of Debate Participation

In the ITAE course debates, a previously selected learner plays the role of moderator, being responsible for the coordination of the debate session. First the moderator returns to each question previously discussed in the seminar. Next each learner sends in a comment about the question. Then learners elect one of the comments for further discussion. After the discussion, participants summarize what was discussed and present their conclusions. After discussing the third question, mediators declare the end of the debate and subsequently evaluate the participation of the learners.

To evaluate a debate session, mediators score the messages that have been sent: 10 is given to a message whose content is related to the debate subject; 5 is given to a message whose content misses the debate subject; and 0 (zero) is given to a message that interrupts the debate dynamics (for example, messages that are sent after the moderator requests “silence” or “attention,” since they hinder debate coordination and disrespect moderator’s authority). For a message to be given the top mark it only needs to be related to the subject being discussed and appropriate to the dynamics—for example, it does not take into account grammatical errors. The emphasis of the debate is on the exchange of messages, being established that each learner must send a minimum of 20 messages per debate (Minimum Quantity model).

As a result of the debates held during the running of the ITAE course, it has been identified that the use of chat makes it possible to constitute a space to explore new educational methods where there is an absence of expositive content, there is a high level of dialogue and the teacher no longer is considered to be a repository of knowledge and conveyor of the truth. It has been identified that informal conversation allows learners to be more aware of others and to be more aware of themselves as part of the group, offering space for showing their emotions, reducing this way the sensation of impersonality and isolation. The continuous and integrated use of chat tools in educational activities is a way of keeping learners motivated and engaged in order to ensure the success and continuity of the distance learning course. The assessment of participation is an appropriate instrument for equating chat activities with other course activities.

4. ASSESSMENT OF COMPETENCE

In AulaNet, a learner’s competence is characterized by three dimensions: Qualification, Interest and Performance (Fuks, Mitchell, Gerosa & Lucena, 2003). Interest and Qualification are indicated by the learners themselves. Performance is calculated by the AulaNet environment according to the results obtained in the courses. For example, in each ITAE course seminar, the average grade of the learners’ messages influences their performance in the subjects taken up in the seminar.

In order to visualize learners’ competence, the AulaNet offers a Competence Report. The assessment of competences is still underway in the AulaNet. This study was initiated out of the necessity to form groups of learners based upon their interests, qualifications and performance with regard to course topics. The first solution investigated was for the AulaNet environment itself to assemble groups using software agents (Cunha, Fuks & Lucena, 2003). The automatic grouping was not satisfactory, generating groups of learners that the mediators considered inadequate. Then, the strategy of supplying reports as described in this paper to enable the mediators themselves to form the groups was adopted.

5. COLLABORATIVE ASSESSMENT

Collaborative learning requires collaborative assessment. When learners share assessment responsibility, there is an increase in assessment comprehension and utility (O'Sullivan, 2004; McConnell, 2002). For those being evaluated, multiple assessments of their work generate greater trust of the assessment results. With practice, learners who make the assessment come to better understand the process and objectives of the assessment procedure, enhance their critical senses and are more capable of appraising their own work.

5.1 Collaborative Assessment of the Seminar Messages

As of the 2000.1 edition, when the ITAE seminar messages were first graded, learners in almost all of the editions have suggested collaborative assessment of the seminar messages. The use of this assessment strategy is being planned. In each seminar, some learners will be selected to evaluate messages. Mediators will continue making their assessment; however, their grades and comments will only be published after the seminar is over so as not to influence the appraisal of the evaluator-learners. Concluding this assessment process, the author of the message conducts a self-assessment, taking into account all the grades and comments the message has received. The final grade of the message will be the average of all assessments. The Conference service must be modified in order to make this collaborative assessment of seminar messages method feasible. New mechanisms are already being developed to support collaborative assessment in the AulaNet environment and the method planned will be tested during the next editions of the course.

5.2 Collaborative Assessment of the Content Developed by Learner Groups

In the second stage of the ITAE course, learners develop new contents about the subjects studied and discussed during the course. This stage of the course begins with learners being organized into small groups (Section 4). Next, each group submits a prototype of the content. Learners themselves evaluate this prototype. Based upon the assessments, each group modifies the prototype. The final version then is evaluated by the mediators.

The collaborative assessment of the prototype is carried out through the Conferences service. For each prototype, a conference is created where learners analyze the prototype, based upon some criteria that have been established. Then, the developers must initiate a discussion of the problems identified in the prototype.

The adoption of this assessment strategy has shown that mediators and learners are not familiar with collaborative evaluation. Learners fear criticizing other learners' work and cheating such as "assess me well and I'll do the same for you" are prone to happen. Learners also react to other learners' criticism. Self-assessment, an essential part of collaborative assessment, has an additional obstacle in the sense that it is very difficult for one to be impartial about oneself. Future research must be conducted in ITAE course to investigate these problems.

6. CONCLUSION

The assessment strategies normally employed in traditional classrooms are not sufficient for the collaborative learning conducted in online education environments. In this article, there was a discussion of the assessment strategies that have been developed and tested in an online course: participation follow-up, competence management and collaborative assessment. While these strategies still need to be improved, and the AulaNet environment is being modified to provide more support for them, it can be concluded that these strategies have made it possible to more adequately evaluate the learners.

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Mediated Chat Development Process: Avoiding Chat Confusion on Educational Debates

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Abstract. The objective of this research is to reduce confusion in chat conversation, which is the main problem regarding the use of chat tools for holding online course debates. This problem is investigated using a Groupware Engineering approach. A number of successive versions of the Mediated Chat tool have been developed as part of this research. This research aims at producing an enhanced chat tool designed for educational debates through which a chat conversation could be followed more easily.

Keywords: Chat Confusion, Education Debates, Online Education

1. INTRODUCTION

Textual chat tools have achieved widespread popularity and, increasingly, people want to use these tools in activities that go beyond socialization and recreation. In this research project, a chat tool for running synchronous debates as part of online courses is investigated.

Among the potential educational uses of chats is the establishment of a space to explore new educational models where there is an absence of expositive content, a high level of dialogue and the de-characterization of the teacher as a repository of knowledge. It has been identified that informal conversation, which is typical of this tool, makes it possible for learners to better perceive others and to better see themselves as part of the group. This provides a space for emotions that reduce the feeling of something impersonal and isolated. The continued and integrated use of chat tools for educational activities is a way of keeping learners motivated and engaged in order to guarantee the success and continuity of distance learning courses.

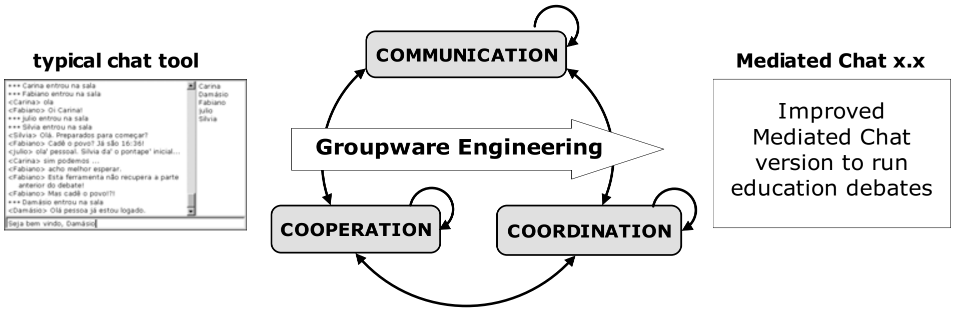
However, conversational confusion has been identified as the main limitation of the educational use of chat tools. The participants of the synchronous debates being researched, although usually excited about the activity, frequently complain about the chat confusion: “It is not easy to communicate through such a chaotic tool”; “I liked this debate…however, I couldn’t follow what was being discussed very well”. In a chat with a number of participants talking at the same time, the result is a tangle of messages where it is sometimes difficult to identify who is talking to whom about what. This problem has been called Chat Confusion (Pimentel, Fuks & Lucena, 2003; Thirunarayanan, 2000).

The objective of this research is to discover which problems cause the participants to consider the chat conversation confusing. Using a Groupware Engineering approach, problems have been identified and mechanisms for chat tools that can avoid chat confusion have been developed—this research methodology is presented in section 2. For each problem identified, a new version of the Mediated Chat tool is developed and then experimented within an online course—the versions and their evaluations are presented in section 3. The conclusion of this research is presented in section 4.

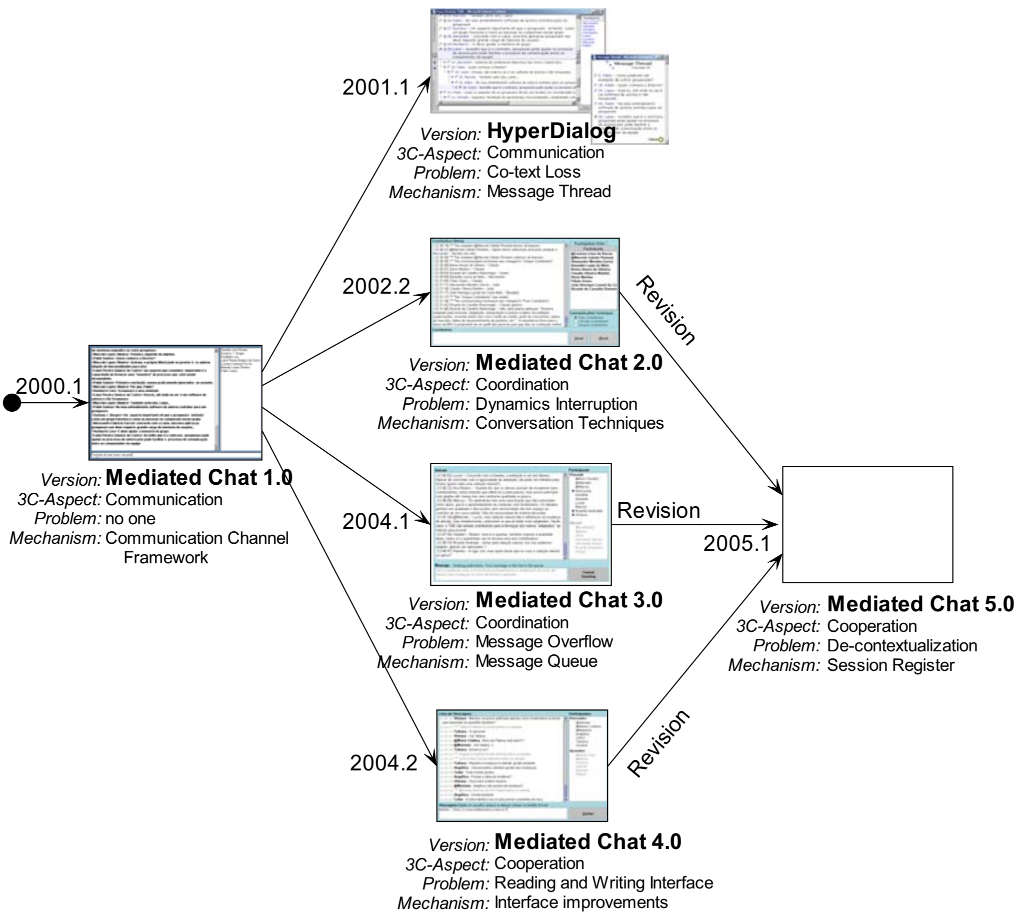
2. GROUPWARE ENGINEERING TO DEVELOP THE MEDIATED CHAT TOOL

The AulaNet environment is a Learning Management System based on a groupware approach that has been under development since June 1997 by the Software Engineering Laboratory of the Catholic University of Rio (PUC-Rio). The AulaNet is a freeware application available in Portuguese, English and Spanish versions at http://groupware.les.inf.puc-rio.br and http://www.eduweb.com.br. The group that is developing the AulaNet learningware also teaches the Information Technology Applied to Education course, ITAE (Fuks, Gerosa & Lucena, 2002), in the Computer Science Department at PUC-Rio. This course has been taught entirely online through AulaNet since 1998.2 (the second semester of 1998). This course provides a real environment where the experiments related to AulaNet are carried out. Among the ITAE course’s activities are synchronous debates held through the AulaNet Debate service, which runs the Mediated Chat, the chat tool being researched.

To guide the research of problems related to chat confusion and to systematize the development of Mediated Chat versions, a Groupware Engineering approach has been used (Fuks, Raposo, Gerosa & Lucena, 2004). It is based on a collaboration 3C model: Communication, Coordination and Cooperation. These concepts are used to analyze the ITAE debate sessions in a search for problems related to chat confusion. For each problem identified, a new Mediated Chat version is developed, as in the process shown in Figure 1.a.



(a) Groupware Engineering applied to the development of the Mediated Chat tool



(b) Mediated Chat versions

Figure 1. Mediated Chat Development Process

Each new Mediated Chat version implements a mechanism to solve a problem related to chat confusion that has been identified. The development process is presented in Figure 1 and described on the next section.

3. MEDIATED CHAT VERSIONS

This section describes each Mediated Chat version developed focusing on the problem identified, the mechanism implemented, the data collected from its use on an ITAE edition, and its evaluations.

3.1 - Mediated Chat 1.0: the typical chat tool

Despite few features, Mediated Chat 1.0 is a typical chat tool. The development of this version had not been driven by an effort to solve a chat confusion problem. The main objective was to support the synchronous textual message interchange between the participants of an AulaNet course.

When the Mediated Chat 1.0 was first used to run the debates on ITAE 2000.1 edition (first semester of 2001), the participants considered the chat conversation too confusing. This research project started to investigate the causes of chat conversation confusion aiming at developing a Mediated Chat tool through which debates would be better understood.

3.2 - HyperDialog: Co-text Loss and the Threaded Messages

Among the symptoms of conversation confusion, the occurrence of Co-text Loss was identified; a problem that occurs when one participant is not capable of establishing the structure of the discourse—that is, s/he cannot identify which message (prior to the given message) is being answered. Analysis of the linguistic aspects of the ITAE2000.1 debates led to the hypothesis that one of the causes of chat confusion was the non-linearity of the chat session messages (Pimentel, Fuks & Lucena, 2003). The HyperDialog tool, where messages are threaded, was developed in order to deal with the Co-text Loss problem. Besides presenting messages chronologically ordered, the tool also presents the tree message associations. In this organization, the text sequences—the way in which the dialogues are linked together—are evident. In an isolated thread, the conversation remains linear: each message is associated with the message that comes immediately before it. The thread mechanism would reduce the occurrence of co-text loss because it organizes the non-linearity of the chat.

Contrary to what was expected, the experiment held in 2001.1 showed that the Co-text Loss problem was not reduced using the HyperDialog. It was noted that co-text losses through the use of the HyperDialog tool were accused regarding the messages where the sender had not specified the association with the message s/he referred to. When the messages are not adequately associated (7.5% of messages were not correctly linked), the threads become useless and can make it even more difficult to identify the co-text. While the message thread mechanism has the potential to prevent the Co-text Loss problem, it nevertheless introduces other problems. The conversation became inappropriately more formal. The message tree structure dispersed the participants who were focused on different branches, making coordination of the debate more difficult. Compared to typical chat tools, HyperDialog used a much more complex interface that introduced a number of problems regarding the use of the shared space.

The thread mechanism implemented in the HyperDialog tool is similar to that implemented in Threaded Chat (Burkhalter, Cadiz & Smith, 2000), and the users who experimented the Threaded Chat tool also indicated that it was significantly worse than a typical chat tool. In future works, a simplified version of the thread mechanism will be researched.

3.3 - Mediated Chat 2.0: Dynamics Interruption and Conversation Techniques

To systematize and facilitate coordination, a better defined sequence of steps for the ITAE debates was established. The dynamics, applied as of the ITAE 2002.2 edition, prescribes a set of activities and expected messages for each debate step. Using this better structured conversation dynamics, the debate session becomes easier to follow. Compared to the preceding editions, there was a reduction of Co-text Loss by half in the ITAE 2002.2 edition—an indication that better conversation flow implies in less chat confusion.

The application of these new dynamics made it clear that some of the messages were not appropriate for the ongoing step, being identified as Interruptions (Pimentel, Fuks & Lucena, 2004). Nevertheless, the Mediated Chat 1.0 tool, as well as the majority of typical chat tools, does not have specific mechanisms to support coordination (Pfister & Mühlpfordt, 2002). For that purpose, the Mediated Chat 2.0 tool implements the following set of conversation techniques: *Free Contribution*, where participants can send messages at any time; *Circular Contribution*, where participants are organized in a circular queue and, one by one, the first one in the queue can send a message; and *Unique Contribution*, where each participant must send a single message at any time. It is also possible to *Block-Unblock* the sending of messages by the learners.

The number of Interruptions characterizes the difficulties in coordinating the debate session (the perfectly coordinated stage is one in which no Interruptions take place). It was expected that the use of the conversation techniques implemented in Mediated Chat 2.0 would reduce the occurrence of Interruptions resulting in a better debate coordination and, thus, in less chat confusion. However, the experiment conducted in the ITAE2002.2 edition showed that the number of Interruptions remained unchanged when the Mediated Chat 2.0 was used. A further analysis of these sessions pointed out that the interruptions took place because the conversation techniques are too rigid to deal with unexpected situations. Improvements on the mechanisms tested were proposed (Pimentel, Fuks & Lucena, 2004) and then implemented on the Mediated Chat 5.0 version (subsection 3.6).

3.4 - Mediated Chat 3.0: Message Overload and Message Queue

Another problem related to chat confusion frequently mentioned by learners is the difficulty in reading all the messages during the debate session. This problem is aggravated when a large number of messages are exchanged within a short period of time, making it impossible for participants to read all of them. In this research this phenomenon is termed Message Overload. A similar problem is known as Flood in the IRC literature (Oikarinen, 1993). However, Flood is the high rate of messages sent by a single participant, whereas Message Overload is the high rate of messages sent in the session by all participants.

Mediated Chat 3.0 tool was developed to deal with the Message Overload problem. In typical chat systems, each message that the server receives is immediately dispatched to the clients. In the Mediated Chat 3.0 tool, the server waits after publishing a message and before publishing the next one, allowing the participants to read all the published messages successfully. This mechanism was based on the Chat Circles tool (Viegas & Donath, 1999), where the message remains visible for a limited period of time. However, in the Chat Circles tool there is nothing that prevents other messages from being simultaneously presented, thus Message Overload may still occur. In addition, in both tools there is the indication of a typing-participant represented by a pulsating circle.

The Mediated Chat 3.0 tool was used in the ITAE 2004.1 edition. The interviews that were conducted with the participants demonstrate that nobody complained about message overload. However, a lot of the participants did not become aware of the message queuing mechanism. Some of them thought that the chat tool was too slow because some of their messages had their publication delayed (their message was in the queue but they did not notice it) and were unsatisfied with the new version. To deal with this collateral problem, the Mediated Chat 5.0 version (subsection 3.6) implements the queuing representation in the Participant List in such a way that it is more visible and easier to understand, similar to the one implemented in the PalTalk tool. The typing indication was quickly and well understood by the participants and aided the chat coordination. This mechanism also reduces the occurrence of a specific type of interruption caused by the lack of visibility of turn in progress (Vronay, Smith & Drucker, 1999).

Although not conclusive yet, the results show that the queuing mechanism used in this version prevents Message Overload, and the typing indication prevents the interruption caused by lack of turn in progress. Both mechanisms help chat coordination reducing chat confusion.

3.5 - Mediated Chat 4.0: Interface to a better Reading and Writing process

Some problems concerning the reading and writing process causing chat confusion have been identified. Then, Mediated Chat 4.0 was developed. To improve the reading process, the debate session text is formatted to increase the visual distinction between different types of information: date published, sender and the content of her/his message; messages of participants and messages automatically sent by the system (to inform who entered or left the debate session). Only the nickname of the participant is presented, not his/her full name, to decrease the amount of text identifying the sender. The scrollbar stops scrolling automatically when the reader scrolls it up to read the messages no longer visible on the screen, and resumes scrolling automatically when the reader scrolls it down to the last published message. To improve the writing process, the typing area increased to 3 visible lines of text (instead of just one).

The versions Mediated Chat 1.0 and 4.0 were used to hold the ITAE 2004.2 debates. The participants were interviewed and they all stated that the new interface helps reading the published messages and to writing new ones. New interface improvements were suggested by the participants during the debate sessions and interviews. They were analyzed and then implemented on Mediated Chat 5.0.

3.6 - Mediated Chat 5.0: Session Register to avoid De-contextualization

All mechanisms tested in previous Mediated Chat versions were revised and implemented in Mediated Chat 5.0. The latest version is going to be experimented in the ITAE 2005.1 debates. The objective is to find out the degree of chat confusion that occurs when using all these mechanisms together.

A new mechanism developed to avoid the de-contextualization problem (Hedestig & Kaptelinin, 2002) will also be investigated. This problem happens when a participant enters an ongoing debate session. The other participants will be already engaged in the discussion and the new participant will find herself de-contextualized having difficulty to follow what is being discussed and delaying her participation in the session. Sometimes, the debate dynamics is interrupted to contextualize the participant that just entered.

To avoid the de-contextualization problem, the session control mechanism was implemented in Mediated Chat 5.0. The mediator is the one responsible to start and finish a chat session. All messages sent during a session are archived by the chat server. All messages produced during the ongoing session are presented to the incoming participant, enabling her to find out the context of the ongoing discussion.

4. CONCLUSION

This paper addresses chat confusion. This phenomenon is investigated within the educational debates setting. Evidence comes in the form of: co-text loss, dynamics interruption, reading and writing interface features, and de-contextualization. Using a Groupware Engineering approach, a chat tool has being developed seeking to prevent this phenomenon. The newest Mediated Chat version derives from the systematic investigation of the influences of communication, coordination and cooperation aspects of educational debates through chat sessions. Although the experiment with this latest version has not been conducted yet, the results obtained with the use of intermediate versions indicate that debate sessions will be less confusing and more understandable.

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Computer-Supported Collaboration in a Scripted 3-D Game Environment

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Abstract. The particular focus of this paper is on scripting collaboration in a 3-D virtual game environment intended to make learning more effective, but also take into account the risk of over-scripting learning. The empirical experiment eScape, which encourages learners to solve problems collaboratively, is also presented. This study attempts to find out whether the features of 3-D games can be used to create meaningful scripted collaborative learning environments. The results indicated that scripting persuaded student teams to enter into collaboration, but the actual processes varied.

Keywords: CSCL, scripting, 3-D virtual game

INTRODUCTION

To respond to learning demands, CSCL (Computer-Supported Collaborative Learning) (Koschmann, 1996) needs instructional support. Structuring the interactions taking place during the virtual learning period is one specific way to make collaborative activity more efficient. Structures that construct collaborative processes are called collaboration scripts (Dillenbourg, 2002). A part of current research on structuring CSCL is derived from earlier work on the approach based on scripted cooperation (O'Donnell, 1999). Scripts are intended to facilitate collaborative learning processes and guide learners' activities. Scripts make it possible to specify and sequence activities and roles and assign them among the members of the team engaged in collaborative work. (O'Donnell, 1999; Weinberger, 2003). Scripts may help learners to enhance the quality of their learning processes. However, designers of scripts must also take into account the risk of over-scripting learning, which may hamper natural interaction and problem-solving processes, increase the participants' cognitive load or harness their collaborative load to serve didactic purposes and purposeless interactions (Dillenbourg, 2002). Accordingly, it may be said that scripting CSCL is about balancing between helpful and excessive guidance.

Last few years have witnessed an increase in interactive gaming, though this growth has taken place mainly in the field of entertainment games. Recently, has aroused a discussion about whether collaborative virtual gaming could also promote learning. Game worlds have the potential to draw on the feeling of presence and immersion which virtual worlds can arouse at its best (Mc Lellan, 1996). More sophisticated technical applications will make avatars increasingly capable of supporting non-verbal communication between students, which may make interaction between players more efficient (Cassell & Vilhjálmsson, 1999). At their best, well-designed multiplayer games may enable engaged communication and collaboration between players during the gameplay.

Adopting games as a resource is often justified on the basis of motivational factors. However, even though games may motivate learners, there are critical issues involved in gaming. One of the major ones is that in learning, games must be put to pedagogically reasonable uses and playing must go beyond aimless enjoyment, become a purposeful activity that requires mental effort. Scripting interactions is a natural idea in game design because games are often based on different levels of activities. One possible way in which games can motivate players is the provision of higher game levels that may be reached by solving problems set in the game. For example, the higher level may offer new scope for action or give access to more tools which help the player to survive in the game. The aim of future learning games is to use scripts and different game levels in a way which supports high-level learning and pedagogically reasonable aims (Hämäläinen & Häkkinen, 2004).

RESEARCH AIMS

The study is a part of the ECOL (Ecology of Collaboration) research project, whose purpose is to examine collaborative learning as a motivated and co-ordinated activity. The eScape virtual game is a pedagogical innovation involving the development of a technological tool intended to create settings for collaboration and increase participants' awareness of the social processes going on during collaboration. The study designed and tested game players' activities in an eScape virtual environment with the aim of finding out whether the features of 3-D games can be used to construct meaningful virtual learning environments. As regards to eScape, the aim is to answer the following questions: 1) What kind of scripting promoted collaboration in the eScape game environment? 2) What kind of interaction emerged during the game?

THE ESCAPE GAME

In eScape (Electronically Shared Collaborative and Pedagogical Experiment), the main focus was on constructing a game environment that would promote collaboration between team members and support the process of becoming a team. The game includes puzzles that can be solved only through the effort and commitment of every participant. To encourage collaborative activities, the game world consists of a small-scale thematic setting that channels and constrains the players' activities. Shared workspace collaboration revolves around certain core activities that need to be supported: 1) communication and negotiation between group members, 2) keeping track of other group members' work, and 3) stimulated physical activities such as moving tools and objects (Pinelle, Gutwin & Greenberg, 2002).

eScape is a collaborative game for four players which can be characterised as social-action adventure. The game concept involves an escape story where the group must solve a set of problems in order to flee from an ancient prison colony. It was decided to design, or script, significant key points at which collaboration was expected to take place. The scripting was hidden from the players behind the game's escape story. Due to the limited duration of the experiment, the content of the game enables approximately 60 minutes of goal-oriented activities. The players interact and experience their surroundings by using their modifiable avatars in an atmospherically captivating virtual world. Role play and player-to-player communication are supported through versatile non-verbal communication (expressions, gestures, etc) and a voice-over IP speech system which allows free spoken dialogue between the players. The main challenge in design was the scripting of motivationally guided logical and challenging problems that would require true collaboration.

RESEARCH DESIGN

This study is a design experiment, involving both the process of designing a game environment and an empirical study, where data is collected using multiple methods and then analysed, after which the findings and conclusions serve as a basis for further design work (Cobb, Confrey, diSessa, Lehrer & Schauble, 2003). The data was aggregated and analysed at the group level. The qualitative analysis was partly theory-driven (Webb, 1989) and partly data-driven. A special laboratory environment was constructed so as to capture all the required data during the experimental game sessions. The multiplayer aspect of eScape meant that all the actions of every player must be recorded. The eScape empirical experiment was organised in 2003 with the participation of university students chosen from the non-gaming community. Six groups of four students (N=24), four of them composed of Finnish students, two of foreign students, took part in the experiment. On the first day the students were given an hour's training session in the game environment. On the second day they played the game, immediately followed by a stimulated recall interview. Data were gathered using several methods: background information questionnaires, video feed from each of the players (over-the-shoulder view), combined views from all the four players (over-the-shoulder views), video feed from a virtual camera (inside the game world, used by one of the game operators), audio recording of spoken dialogue, demo recording within the game platform (enables free camera movements during playback), observation notes, stimulated recall interviews, and the students' personal notes.

DATA ANALYSIS

After the game experiment, all the data were verified, interviews and conversations conducted during game sessions were transcribed and observation notes were sorted into categories. A qualitative analysis was carried out using data classifications. In the first stage of classification the data were categorised according to the problems scripted (key collaboration points) into the game environment. The second stage of the classification focused on the significant situations identified on the basis of the script. There were two stages. The first stage pinpointed the interactions that were the central facilitators of game progress. After this, the situations identified in the first stage were analysed to find out, on the basis of observations, what were the (individual and group) interactions that the players used, followed by an examination of their contribution to collaborative group activity (Table1).

After the building: Peter asks the other players: "So we have to look for more?". The other players answer yes, and

Peter starts to move quickly around in the game environment, carrying the box.
other players: rule-making
After the building: Peter wants to know which of the players is talking. All the same, he is operating well on his own in the game environment, carrying the box along.
identifying a target (personal)
After the building: Peter tries, alone, to use the boxes to build a platform from where he would jump over the wall and fence surrounding the castle. He does not tell any of the other players about this target.
No negotiation
After the building: Peter listens as the other players tell each other about the biting bees. Instead of going to help he continues on his own to build the platform for clearing the wall and fence around the castle.
identifying a target (personal)

Table1: An example of observations on individual and group activity

Cross-comparisons of sets of research materials collected using several methods were intended to improve the reliability of the research results.

RESULTS

According to the findings, scripting enhanced collaboration during the game. Despite the scripted environment, group and individual actions varied a great deal. The groups differed in the time spent on the game, the degree of collaboration shown, the roles assumed and the attitudes displayed by their members. Scripting guided team members towards collaboration and shared problem-solving. Despite the scripting, the time spent on the game varied from about 45 minutes to 1 hour and 20 minutes. According to the accompanying data analysis, five of the six groups had achieved good collaboration at least some points of the game, while even the non-collaborative group had managed some teamwork. The five collaborative groups followed the predefined order of scripted game tasks (Table 2).

Phase 1	Encouraging the group members to communicate
Phase 2	Planning the activities and getting to know the 3-D environment (requires *planning, goal-setting and -seeking, negotiation, co-ordination and rule-making*)
Phase 3	1st problem: getting a box from a high scaffold (requires a working plan)
Phase 4	2nd problem: getting nests from a colony of bees (requires forming dyads)
Phase 5	3rd problem: helping a blind man (requires forming groups of three or four members)
Phase 6	4th problem: firing a rocket pattern into the sky (requires *goal-setting and -seeking, planning, negotiation, co-ordination and rule-making*)
Phase 7	5th problem: constructing a hot-air balloon (requires contribution by all four members).
Phase 8	Stimulated recall and reflection (30 minutes)

Table 2: Scripted key points of the game

The game problems encouraged teams to work together. These five groups attained at least some degree of collaboration during the game although the quality of their collaboration varied a great deal even in groups immersed in game situations. For the purposes of collaboration, it was essential that the first problem the members of a team encountered in the virtual environment encouraged them to communicate with each other. Interestingly, even the non-collaborative group, reflecting on the game after its completion, felt that they had been collaborating. Collaboration emerged mostly in the problem-solving situations, and more often on the level of practical activities than on the cognitive level. The results indicate that in order to obtain collaboration it was crucial to construct tasks that compelled players to work together. In eScape, most of the problems were set in a way which made it impossible to solve them alone. However, most of the players first attempt to solve the tasks on their own, joining forces with the other players only when they realise that they are stuck. With many of the players, perceptions of collaboration clashed with observation notes: students felt that they had mostly tried to solve the problems as a team, but observations indicate that most of the players called for other players only when they actually needed their help. Only one of the six groups made, in the early stage of the game, a joint decision that they would work as a team to get through the game.

The scripted game environment enhanced the value of distributed teamwork. The players felt that they had been in the same world operating as a team, and observation notes confirmed this subjective finding. None of the teams had sensations of being alone or engaged in aimless interaction. The experiment integrated distributed CSCL and face-to-face interaction. The students met before the game, and afterwards, during the stimulated recall interview, they were shown extracts from the game video and asked to watch and comment on them. After the game the students were very eager to talk with each other about the game and find out about those aspects of the game environment that they had not understood during the game. This showed that reflection after the game was important.

During the game, the groups used different interaction processes to solve the game problems. These processes were applied mostly in problem situations and in situations where the team members were about to collaborate on the solution of a problem. All the groups **set themselves goals**, but the actual decision-making process ranged from group decisions to leader-oriented ones. The group decisions affected the game and the process of becoming a team in different ways at different stages of the game session. The players had roles although many of them were clearly not themselves aware of these, as was revealed in the interview after the game. For example, in some groups the game was dominated by one or two players who worked out the plans and told the others what to do, but in some situations leadership shifted according to the players' level of expertise. It is interesting to note that all groups felt that they had collaborated as reasonably equal partners even when the group had actually had a leader without their being aware of it. Croups **formulated low-level action plans**, but no group used much time to devise their plans. All the groups **negotiated** among themselves and **co-ordinated** their work to advance the game. In the following excerpt, there is one low-level action plan during the game.

Leila: Look, there are several places over there. How about going there all together and guiding him away from there. Tuija: I expect we'll need everyone here. Here in this place. I'll go and stand in the doorway over there. Leila: Hi there, who's there, come here. Mira: Where are you?

Throughout the game, group members **shared information** and **followed the example of each other's avatars** to further the gameplay. They shared information and learned from each other in a great variety of situations, such as when working out how certain tools functioned, how to use the avatars, what kind of individual knowledge the different players had and so on. See the following excerpt about sharing information how to use mouse.

Mira: How can I take these tools to my hand? Leila: Roll your mouse and then it will choose	9:02:46 The nest: Mira asks Leila how one uses the tools and Leila shows her how one uses the mouse to a turn. XXXX
Game situation	Observation note

During the game the groups also **made rules** on how to act in certain situations. Few of the rules were intended to limit the actions of the avatars during the game, and those made for this purpose related mostly to the last problem, which required group members to use certain tools simultaneously. All the teams also **gave feedback** and encouraged their members. There was no negative feedback in the form of personally disparaging remarks in any of the groups. The negative feedback that was given focused on the environment in situations where it did not work in the way the players expected. Feedback was most frequent in problem-solving situations and after a problem had been solved. See the following excerpt about feedback situation.

Mikko : Really close (3) Now we should be close by Juuso: Now? Yes Mika: Do you see it 13.24 (trumpets) Mikko: Splendid Juuso ( ) you are our hero	Players encourage each other
Game situation	Observation note of all players

In all groups, there were situations in which **players found it difficult to give up their own ideas** even when their proposed solution did not make sense in the game environment. In many such cases the players kept on advising each other or tried to solve the problems on their own. The most collaborative group was also the one most open to mistaken ideas. **Conflict** situations during the game were rare. When conflicts did arise it was because players did not understand or find each other. Thus, the game environment failed to create significant cognitive conflicts. However, there were occasions during the collaboration that involved tacit conflicts. For example, records show occurrences of seemingly increased levels of frustration on behalf of a player when nobody paid any attention to his or her suggestions.

All the groups **used humour** to establish relations between players even though it was not necessary for solving the game puzzles. Humour was employed to make contact with other players, survive surprising situations and liven up the atmosphere. Humour was most in evidence in those groups which had some history of being together, least in evidence in one of the foreign student groups. How much and what kind of humour there was varied both between the groups and within every group. For example, during the game the players tried to work out the similarities and differences between the game world and real world: will avatars break when they jump from a height. Some ethical issues also arose, such as whether one can open the church door using a rocket.

DISCUSSION

Our study supports some of the previous findings about essential interaction processes of collaboration, such as joint goal orientation, negotiation, co-ordination of different perspectives and information sharing (Baker, 2002; Pinelle, Gutwin & Greenberg 2002), but in game environment new forms of collaboration may also arise. In this study the 3-D game world affected collaboration, for example information sharing, because players were able to use the example of the avatars to share information. In this study, students' perceptions of a scripted game environment were very positive. Scripting persuaded student teams to enter into collaboration, but the actual processes varied. Collaboration depended crucially on team members' need for each other, because they often tried to solve the game tasks alone first. According this study scripting social modes of interaction seems to be an effective way to promote collaboration in the virtual gaming. Despite of positive influence of the scripts, there are also some critical issues such as the relationship between players' internal scripts and external scripts of the environment (Kollar, Fischer & Hesse, 2004).

The study produced encouraging results on the possibilities of edugames, but some dangers were also identified. The study indicated that it is easy to obtain collaboration on practical problems but that higher levels of collaboration are difficult to reach in a game environment. One explanation for this result is the design of relatively simplistic and secure problems, which enabled safe trial-and-error procedures. The findings show that a virtual game environment offers a setting that can, at its best, trigger several interaction modes of collaborative learning. At the same time, attention must be paid also to the variation across the groups in the quality of collaborative activity. Technology alone, does very little to aid learning. Learning crucially depends on the exact character of the activities that learners engage in with technology, the kinds of tasks they try to accomplish, and the kinds of intellectual and social activities they become involved in, in interaction with that which technology affords. Furthermore, more edugames are needed to determine the potentials and limitations of games.

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Mining Learning Groups' Activities in Forum-type Tools

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Abstract. Mining data produced by students involved in communication through forum-like tools can help revealing aspects of their communication. In this paper we propose an approach to the construction of models to highlight structural properties of learning groups based on a relational perspective (analysis of chains of references) and the use of Social Network Analysis techniques. These models can be useful both for the tutor and the participants. We begin by introducing the overall approach, then we describe how the models are constructed and finally we present preliminary results from the integration of these ideas in a forum-type tool.

Keywords: Link analysis, peer-to-peer support, social network analysis.

INTRODUCTION

Network technologies have enabled web-learning activities such as learning groups and e-communities that can take place in e-learning platforms. Traditionally, collective activities of these groups take place in what we call a *forum-type tool* (FTT). The FTT describes a mainly text-based and asynchronous electronic conferencing system that makes use of a hierarchical data structure of enchained messages, called *threads*.

In this paper we are interested on supporting collective activities that take place in learning groups based on a relational model of messages exchanged among participants in a FTT.

We model the message exchanges as a graph where the vertices are the participants of a group and the links are the exchanges among them. This is a basic model broadly used for modeling relationships among users from a social networks analysis point of view. We exploit the group's link structure to contribute to a comprehensive understanding of the group activities.

In this article we propose the use of two models to gather information about group activity from a relational perspective. Each of these models corresponds to a different granularity of the analysis. The first model denotes properties of the group as a whole; the second denotes properties of the individuals in relation with the group to which they belong. Our algorithms construct indicators that allow characterizing the collaboration process, which can be useful for both tutors and students.

The article is organized as follows. First, we describe the idea of mining group activities and their use in a CAL context. Then, we propose and describe two models to gather different characteristics of a group. Finally, we present preliminary results from an empirical study that illustrates the use of our models.

MINING GROUP ACTIVITIES

Mining group activities in a learning context

Mining group activities is an active line of research. Current research is mainly focused on the construction of indicators of collaborative group's activities aiming at a theoretical or ethnographic analysis of the group (e.g., (Reffay & Chanier, 2002), (Martínez et al., 2002) or (Butts, 2001)) and other social networks works). Nevertheless, these analyses are rarely used to support online collective learning activities.

The use of mining strategies can be an important element in educational contexts. Mining group activities in a learning context provides quantifiable profiles of the groups, which allows to (1) evaluate the collaborative activity that the participants carry out, (2) analyze the link structure of the group, (3) compare the collaborative performance among different groups and (4) predict behaviors, discover link patterns (Getoor, 2003) and collaboration trends. This knowledge can be used and applied directly to support the collaborative activities. In this sense, link models can be an element that helps (1) the tutor on his tasks of collaboration management and that scaffolds the collaborative learning among the participants without needing an extensive review of each group's interactions. (2) the participants of the group (the students), who use link analysis to discover the structural features or activities of their group (what has been termed structural awareness (Gutwin, Greenberg, & Roseman, 1996)).

Link analysis provides a new role for tutors in collaborative environments. Instead of their traditional role in the "transfer of information", the role of tutors is shifted to that of establishing the appropriate conditions to allow the students to get connected to the group (the set of relations) through participation (e.g., as part of a community of practice) in the service of an intention (Barab et al., 1999). The structural models that we propose make salient certain profiles of the groups and their participants which can help to be aware of the group activities and can help orienting the pedagogical strategies. Structural models can help participants of a group to create macro-micro links and facilitate peer-to-peer learning. The macro-micro link is a sociological concept that establishes the theoretical foundations for the influence of interaction structure of a community (macro level) with the local interactions among the participants (micro level) (e.g., (Bourdieu, 1988)). The concept of macro-micro link allows us to focus on the interdependency of the structural regularities of the group with the activities of the participants. Indeed, several learning theories emphasize the influence of social interactions on the individual learning. In the perspective of the communities of practice, for example, learning changes "(…) from the individual as learner to learning as participation in the social world" (Lave & Wenger, 1991).

Moreover, the social constructivist point of view highlights also that knowledge is socially constructed by interactions among individuals (McCarthey, 1992). Indeed, the theory of learning of Piaget (Piaget, 1926) states as a fundamental assumption that the interaction among peers while performing tasks facilitates the learning of concepts. By making salient the structure of interactions in a group we allow the participants to be aware of an important element of learning.

Techniques for mining group activities in a relational perspective

The mathematical tools we use for mining group activities come from the Social Network Analysis (SNA) models. Many methods have been proposed in this field to obtain knowledge about the group from its relational ties. The SNA uses as data the connections among units, which relates them in a system.

We use a graph theory to mining group activities by analyzing the *sociograms* associated to a given group. In FTT a sociogram is a graph where the participants are represented as vertices and the messages that they exchange are represented as the links of the graph. Sociograms can be handled as sociomatrices which are the matricial representation of the graph (more information on the construction of sociograms and sociomatrix can be found in (Wasserman & Faust, 1997)).

PROPOSED MODELS FOR SOCIAL INTERACTIONS

We model two characteristics of social interactions: the status of participants and group cohesion. These models gather information about the group activity at different granularity levels. The status belongs to a family of models that reveal the role of a given participant in the group. The cohesion belongs to a family of models that reveal structural properties of groups: it provides information about the group and not about the participants of the group.

Status

Status definition

In a community, the concept of status represents the "prestige" of a specific participant. The status of a participant is related to his participation in a community as well as the status of the participants which s/he communicates with (Wasserman & Faust, 1997). This concept is not a simple account of the number of user interventions, because it also considers the prestige of his entire neighborhood.

Starting from the participant's status we can find the each participant position in relation to the whole community, and the social structure of this community. Moreover, this indicator can be related to a concept of learning in the communities of practice (Lave & Wenger, 1991), where learning is conceived in terms of participation. In the context of the communities of practice, *learning can be interpreted as an evolution of the status* of a participant from a peripheral participation (low status) towards a central participation (high status) within its community. Through the status indicator, we can measure these evolutions. This model gives participants and tutors an element for comparison among their position in the group and a quantitative measure of their evolution.

Status model

There are several models to obtain the status of participants in a group: *Betweenness-centrality, Closeness-centrality, Degree-centrality and Eigenvector-centrality* (Wasserman & Faust, 1997). Here, we will concentrate on the *Eigenvector-centrality* model because it is the only status model that establishes the value of a participant status taking into account the other participant's status. Consequently, "an actor's status is increased more by nominations from those who themselves have received many nominations" (Bonacich & Lloyd, 2001).

In spite of the precision of this method to obtain the status values of participants in a group, it makes sense only for the symmetrical sociomatrices ($A \rightarrow B \equiv B \rightarrow A$, for example, somebody's brother is a symmetrical relation). In our case, the matrices of interactions in the FTT are asymmetrical ($A \rightarrow B \neq B \rightarrow A$, answering a message is an asymmetric relation). The alpha-centrality model introduced by Bonacich (Bonacich & Lloyd, 2001) presents a generalization of the eigenvectors' model for asymmetrical matrices. Bonacich makes the assumption that the status of a participant depends on two parameters: the external initial status of a participant and the status that is formed starting from the interactions among the participants. By adding the external idea of status to the traditional concept of eigenvectors we obtain equation (1). The complete description of this method is found in (Bonacich & Lloyd, 2001).

$$c = \alpha A^T c + e \qquad (1)$$

In this equation A is a sociomatrix. A^t is the transposed matrix of A. c is a vector of participant's status for the asymmetrical relations. Each component of this eigenvector c corresponds to the status of each participant. That is, if $c = (c(v_1), c(v_2),...., c(v_n))$, the status of participant i is $c(v_i)$. α is a parameter which reflects the relative importance of the external status versus the internal status to determine the final status. We can also interpret α as the status degree of transference from one person to another.

Among the outstanding characteristics of this indicator we emphasize that the status is not related to participation (e.g., in the star graph (see figure 1), the most central participant has the greatest value of status and s/he has never participated), the status is associated with the impact of the interventions of a specific participant on the activity of the group (participant's visibility).

Cohesion

Cohesion definition

Cohesion is a concept related to the diffusion of information in a group (Wasserman & Faust, 1997). In a cohesive group the information is extremely likely to be distributed for the entire group. This fact improves the communication, the coordination and the influence within the group. Cohesion gives a measure of how strong the social relations are in order to maintain the group together (Moody & White, 2000).

From this indicator, users can perceive the ability of the group to hold their members. A group with a high value of cohesion is a group that holds social relations among almost all participants. Consequently, the group could face the departure of some of its participants without destroying it.

Cohesion model

There are several models to obtain the degree of cohesion of a group (Wasserman & Faust, 1997). Bock and Husain propose to iteratively build sub-groups so that the proportion between the number of links in the sub-group and links between the sub-groups does not decrease with the addition of new members. Reffay and Chanier (Reffay & Chanier, 2002) obtain the group cohesion by measuring the degree of reciprocal relations that take place in a forum among participants. James Moody and White (Moody & White, 2000) introduce another concept of cohesion, which is defined as the minimal number of participants who, if removed from the group, would disconnect it. This approach led to obtain hierarchically nested groups, where highly cohesive groups are built over less cohesive ones. We seek to make salient this notion, which corresponds to the definition of k-connectivity (a graph is k-connected if there are at least k independent paths connecting every pair of participants in the graph) in the graph theory. This indicator expresses the property of certain groups to hold their members. Yet, this model of cohesion is very sensitive to participants slightly connected in the group. For example, a group with a complete network configuration (see figure 1) with 6 participants have k-connectivity value equal to 5. Nevertheless, if we add another participant to this group with only one link, the k-connectivity value decreases to 1, i.e., a very low cohesion degree for a group that is still highly connected. So, the real group cohesion is hidden. Thus, we modify the original cohesion model (the minimal number of participants who, when removed from the group, disconnect it) in favor of a concept of cohesion as the minimal number of participants who when removed from the group, disconnect it completely. This model provides a more robust measure of cohesion, even for groups with weakly connected participants.

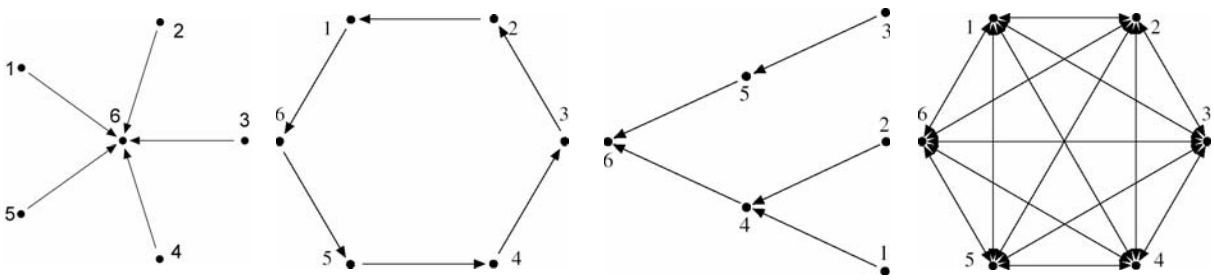
To calculate cohesion, we apply the original algorithm in an iterative way to the groups that remain connected. The summa of the values of the k-connectivity of each iteration will give the final measurement of cohesion. In order to compare the cohesion values for groups of different sizes and structures of participants, these values are normalized. Two normalization methods are necessary: first, in relation to the number of iterations (*j*) executed in the algorithm (i.e., the number of iterations to obtain a group completely disconnected). Second, a normalization regarding the number of participants (*n*). Equation (2) shows the normalized cohesion value:

$$\overline{C}(G_n) = \frac{C(G_n)}{(n-1)* j} \qquad (2)$$

Hypothetical social networks

Figure 1 illustrates four hypothetical social networks with six participants each, with strength of each link equals to 1. The associated status values for each participant ($c = (c(v_a), c(v_b), ..., c(v_f))$), where $c(v_i)$ is the status of participant i . For simplicity, participants in all these social networks, have the same initial status, that is, e is a vector of ‘1’.

In the star network we can observe the central position of participant “6” in it. This fact is reflected by his/her high status value (3.5). The same result is obtained in the hierarchical network. Nevertheless, the low value of cohesion of the star graph structure allows us to suppose that it is fragile, given that all interactions pass through participant “6”. In the circular network, all participants have the same status values because each of them has the same link number and structure. The highest cohesion value is obtained for a complete graph. This fact represents a group highly robust, with multiple channels of communication among participants. We note that status indicator is sensitive to strength of links, but the cohesion indicator does not, because of the nature of the algorithm to obtain the cohesion.



Star network
Status = (1,1,1,1,1,3.5)
Cohesion = 0.2

Circular network
Status = (2,2,2,2,2,2)
Cohesion = 0.3

Hierarchical network
Status = (1,1,1,2,1.5,2.75)
Cohesion = 0.2

Complete network
Status = (5,5,5,5,5,5)
Cohesion = 1

Figure 1. Hypothetical social networks

INTEGRATION OF COHESION AND STATUS IN A FTT

The results of the proposed structural models are integrated in a FTT called "Mailgroup". In this environment, the participants can maintain a discussion by exchanging messages. Mailgroup has been designed according to the objective of supporting learning conversations taking place in forums (Reyes & Tchounikine, 2003). The support provided by such a FTT tool is enhanced by allowing the participants and the tutor to access at any time, through a menu item, to the values of status and cohesion. Mailgroup shows a single bar representing the group cohesion value (group-level indicator), and individual bars representing the each participant status value (participant-level indicator).

EMPIRICAL STUDY AND RESULTS

An empirical study was designed in order to collect feedback on the actual characteristics of the group models from the user's perspective. In this study, 15 participants were recruited. The participants were teachers who, during one and a half months, carried out a distance collaborative activity as part of training course on ICT. During the study, they used Mailgroup as medium of communication and discussion (Reyes & Tchounikine, 2003). The goal of the activity was to carry out a collaborative analysis of the integration and utilization of ICTs in education.

In a first stage of experimentation, indicators are showed only to the monitor of this activity in order to test out the validity of SNA models used in these indicators. Yet, the tutor was able to use these indicators to gather information about the groups' activities. Table 1 shows values of cohesion and status obtained in some real conversations (each conversation equals to different threads) that took place in the carried out experience in Mailgroup. The Cohesion is a single value (in percentage) that represents this property of the whole group. The status is a vector where each component represents the status of a single participant. Consequently the vector has many components as participants in a specific conversation.

For example, from the analyses of indicators of conversation number 3, the tutor saw as an outstanding fact the low value of the cohesion indicator. Analyzing the status of participants we can deduce that there is an unbalanced participation since two users carry out almost the whole conversation. Their participation and central position (high status value) indicate that they lead the conversation. A potential absence of these participants can imply the ending of this conversation or a radical change of interaction structures. This way, both indicators indicate to a tutor (or to users) that it is necessary to change their current social structure: based on the indicators provided by Mailgroup, the tutor might introduce different strategies in order to orient the group towards a more reliable structure, with a more important and balanced implication of the participants in the common task.

Conversations	Cohesion	Status
1	9%	(12, 1, 13, 9, 1, 11, 14, 1)
2	56%	(17, 12, 6, 3, 8)
3	13%	(5, 11, 1, 4, 4, 17, 8)

Table 1. Values of cohesion and status.

CONCLUSIONS

The use of models for mining group activities is an active line of research. In this paper we have presented how we have adapted them for their use for pedagogical purposes: The tutor management and orientation of participant exchanges that take place in a learning group through the tracking of its structural properties.

The pedagogical use of these models is inspired by learning theories and models that emphasize the importance of peer-to-peer interactions and the social structure that they generate. These models can facilitate and even automate the work of tutors in tracking the group activities, helping in focus the attention of the tutor in groups with low levels of cohesion or unbalanced structures of participation.

In this article we have presented two methods for mining group activities based on models for status and cohesion inside a group. The new cohesion model that we have introduced takes into account the general structure of a group, thus overcoming the problem of sensitivity to groups with weakly connected participants. We consider these models as complementary given that they focus on different levels of granularity in the analysis: the group-level in the case of cohesion and the participant-level in the case of status, allowing the analysis of groups in a complementary way.

We showed the results of a test that aimed to corroborate the proposed link models. We obtained that these models describe certain structural properties of a group. Moreover, for the tutor this information can be an element that improves the effectiveness of its pedagogical.

Finally, the models presented in this work are implemented as a part of a peer-to-peer support system: “Structural awareness”. The objective of structural awareness is to make salient the structural properties of a group to its participants in order to promote collaborative interactions and allowing tutors the management of learning interactions and tracking collaborative processes.

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Establishing Communities of Practice among Students and Start-Up Companies

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Abstract. This paper presents the concept and an empirical evaluation of the course "High-tech Entrepreneurship and New Media". The course design is based on socio-cultural theories of learning and considers the role of social capital in entrepreneurial networks. By integrating student teams into the communities of practice of local start-ups, we offer learning opportunities to students, companies, and academia. The student teams are connected to each other and to their supervisors in academia and practice through a community-system. Moreover, the course is accompanied by a series of lectures and group discussions. In this paper we present empirical findings and reflect on changes in the design of the course which took place between its first and the second instantiation. These design changes were based on the empirical evaluation of the first course and a deeper analysis of the role of social capital.

Keywords: Communities of Practice, Social Capital, Regional Start-Up Networks

INTRODUCTION

Engineering universities have a strong record in knowledge sharing with industries ranging from cooperative research projects to student internship linked with the engineering curricula. Start-up companies in the environment of technical institutes heavily benefit from the innovations made in research. Surprisingly, in German computer science the lab courses are not organized according to the model of engineering curricula. Since 30 years, instructors and students have developed an academic practice similar to the practice in the natural sciences. In contrast, many German computer science students are already practitioners in software engineering since they work as software developers for local IT companies often founded recently. German computer science faculties do not encourage entrepreneurship in general. So, even in IT-related start-ups interaction rate between entrepreneurs and academia is low.

This paper describes an attempt to establish an institutional frame between industry and academia to foster knowledge sharing. First, we wanted to draw on the existing practice of students in academic teaching, second we wanted to transport newest methods of software engineering into industry, third we wanted to get access to real world problems of companies to identify innovation potentials on both sides. So, we have developed a new course in computer science teaching which is based on the concept of computer-supported communities of practice. It is called "Entrepreneurship and New Media". Since 2001, we organize supervised student project work together with local start-up companies. The courses are accompanied by a series of lectures in which university lecturers and practitioners address topics related to entrepreneurship and the design of media. A community system is deployed to facilitate communication and document sharing between the different actors.

Besides the development of adequate technical functionalities to support the learning processes, the appropriation of the community system in the context of these innovative didactical concepts is a challenge. The combination of practice oriented education at universities and concepts of learning on the job within companies is a precondition of a successful integration of academic theory and industrial practice. Identity-building in communities of practice and the building of social capital are expected to enable a fruitful exchange between universities' experiences and companies' practice.

In the following, we first sketch our theoretical background. Then we present experiences with the course and its evaluation in two different years (winter term 2001 and winter term 2002). Between the two instances of the course a major design change took place to reflect the evaluation results from the first instance. In the last section we discuss the empirical findings and conclusions with regard to computer supported communities of practice between students and start-up practitioners.

THEORETICAL BACKGROUND

In the last decade constructivist theories of learning played an important role in the development of new computer-based learning designs (Duffy and Jonassen, 1992). In this understanding, learning does not mean the transfer of knowledge from a teacher to a learner, but rather the learner's permanent (re-) construction of knowledge, based on former experiences. Socio-cultural theories take learning as a collective process which is linked to specific contexts of action. Knowledge emerges in communities of practice by discursive assignment of meaning (Lave and Wenger, 1991; Wenger, 1998). Processes of social identification (Tajfel, 1982; Turner et al., 1987) play a central role for the establishment of common practice and a shared identity. To foster networks among student groups, academia, and start-up companies, the scientific discussion on social capital offers a relevant scientific context (Putnam, 1993; Cohen and Prusak, 2001; Huysman and Wulf 2004). Many authors found the concept of CoP helpful to understand and to support cooperation, knowledge management, and collaborative learning (e.g., Brown and Duguid, 1991; Osterlund and Carlile, 2003). Several case studies conclude that this is true even for computer-supported, virtual or distributed communities (e.g., Haas et al., 2003; Arnold and Smith, 2003). The theoretical approach of Communities of Practice (CoP) integrates identity theory, theories of practice, and theories of social structure and situated experience (Wenger, 1998). In their research on situated learning in working groups, Jean Lave and Etienne Wenger focus on common daily practice of group members, active membership, and in-group awareness (Lave and Wenger, 1991). The most important inclusion mechanisms concerning these communities are processes of collective learning and the production of shared meaning and collective identity. In this approach the social practice refers to explicit and tacit knowledge and competencies. It integrates language, tools, documents, symbols, and roles as well as conventions, norms, rules, perceptions, and assumptions.

In CoP, an individual's learning is inherent in the processes of social participation in CoP. Knowledge and learning in CoP are not abstract models but relations "between a person and the world" (Duguid, 2004, p. 8) or "among people engaged in an activity" (Osterlund and Carlile, 2003, p. 3). Individual learning in a CoP is mainly based on "legitimate peripheral participation" (Lave and Wenger, 1991). During the participation process, an individual might enter the community as a beginner at the periphery and then gain a more centered position over time by acquisition of cognitive apprenticeship. This acquisition process leads to an intensified inclusion into the social practice of the community. Learning is based on this process of inclusion of outsiders, becoming more and more insiders in the common practice. The communities of practice themselves can be seen as "shared histories of learning" (Wenger, 1998, p.86). The mechanism of (social) identification of individual persons in the social context of the community plays a key role for the formation of a community of practice. We can see that the CoP approach combines the "two sides of the medal" of community participation: The social practice of the community as a *collective phenomenon* and the identity of its members as an *individual* one. CoP theorists focus on both levels of communality and individuality. Thus, processes of community- and identity-building are central.

EXPERIENCES WITH LINKING ACADEMIC AND START-UP PRACTICE

Based on the theoretical foundations sketched above, we designed the course 'Entrepreneurship and New Media" as shown in figure 1. A major part of learning was supposed to happen by legitimate peripheral participation in the community of practice of the start-up companies. We intended to support processes of social identification and social capital-building between entrepreneurial practitioners and university students. The cooperation of students and practitioners to carry out a common real-world task should allow the establishment of a shared practice and therefore mutual learning. Projects were always related to one of the local start-up companies in the region. Therefore, the companies and the designer of the course developed the projects jointly. We intended to initiate Communities of Practice (CoP) between students and company practitioners in the project groups (cf. big circles in figure 1). By getting start-up practitioners engaged in the group work, a market-oriented perspective was integrated in the course work. Lecturers and instructors/ supervisors were thought to accompany the project work.

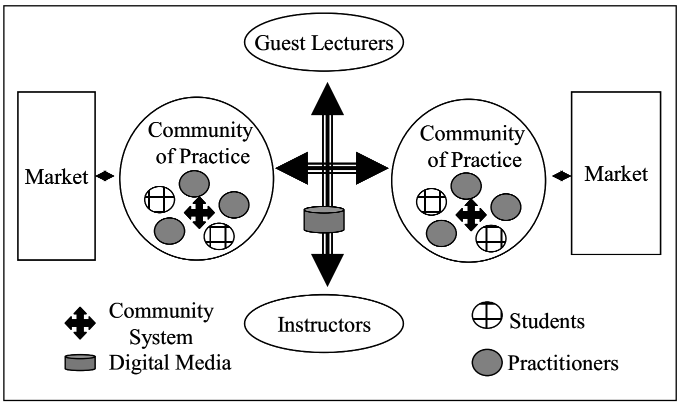

Figure 1: Course Design

Group oriented learning processes, especially among the student teams and between them and their academic advisors should be facilitated by a community-system. Thus, the instructors put task relevant learning materials on the community-system. Additionally, instructors were available for consultancy and supervision. Several review meetings supported the reflective processes of the students related to their tasks. Moreover, these reviews were supposed to work as forums for discussion among students and guest lecturers from industry and academia. While initiating learning processes among the students, the course design supported the knowledge transfer from academia to industry, as well. Discussions between students and practitioners were thought to be the starting point of learning processes in practice. We calculated 50 hours of student time for the course itself and 150 hours for the project lab.

In the following, we shortly describe the evaluation results of the first course and our conclusions for the design of the second one. Afterwards experiences and empirical findings of this second course are presented.

Although the first course (winter term 2001) was rated as successful in general, several shortcomings have been observed: The establishment of CoP between students and start-up practitioners was less successful. In our empirical evaluation we found the following reasons: the start-up companies were *very young enterprises* which had not established *a consolidated own practice*; the start-ups were *very small enterprises* with only few employees and therefore *very limited resources* to supervise the lab groups; the supervisors were *not very experienced* in organizing the course. Furthermore, *socio-cultural differences* between university students and start-up practitioners and *physical distance* between the start-ups and the university caused problems in communication and cooperation. Besides the observation that electronic communication makes peripheral participation in CoP more difficult, the community system (named CommSy; cf. Rohde et al., 2005) *was used not very frequently* by students and start-up practitioners in this first course (cf. Klamma et al., 2003).

According to these results, following changes were made to the second instance of the course (winter 2002): Start-up companies have been selected which were thought to have a *more stable software engineering practice*, and which had been founded earlier and therefore *had a longer history*, and *more employees*. *Bigger student groups* were established (each of the three groups started with six members); each lab group was *supervised by an academic tutor* therefore supervision of the project groups was intensified. Extreme Programming (XP) instead of Unified Modeling Language (UML) was used as *software engineering method*, because XP seemed to us more appropriate for short-term software development projects within smaller teams. The course was accompanied by six students from the department of organizational psychology which supported the lab groups by *intense coaching and training for presentation techniques*. *Four review meetings* were conducted during the second instance of the course (instead of two review meetings during the first one). The reviews were taped on digital video and analyzed by the psychology students to give the lab students *feedback on their review performance*. Finally, *another community system* (BSCW instead of CommSy) was deployed to the course participants and usage of this platform *was motivated by stronger demands* of the supervisors.

The overall learning experiences in this second course have been evaluated quite positively by the students. They mentioned the following factors:

- working on practical real-world problem solutions,
- the cooperation with real partners from start-up companies,
- the cooperation in teams,
- practical experiences with presentation techniques in the review sessions,
- and the method of extreme programming (XP).

However, we believe that we have not yet exploited the full potential of our concept. In the following more detailed results of the evaluation are presented. All reported results are taken out of 25 semi-structured interviews with students, company practicioners, and academic tutors and supervisors) that lasted between 60 and 180 minutes and have been recorded and transcribed afterwards. The reported empirical findings represent condensed interview statements (and observations during the course).

CoP between students and company practitioners

As in the first instance of the course in winter term 2001, the establishment of CoP between students and the company employees was limited again. A *real participation* of students in the companies' communities of practice could not be established. In case of one company, due to the very intense engagement of the company founder, a very good relationship between the entrepreneur and students emerged. The entrepreneur confirms a good atmosphere but is disappointed with regard to the work result, because the competences of students did not fit his expectations. On the other hand, the students and the instructor stated that the task definition was too fuzzy to solve the problems in time. A second lab group showed a different picture: Here the result of the work was very successful while the personal relationships between students and the entrepreneurs were not that good. Fluctuation in the personal of the start-ups and physical distance limited the participation in the company's practice. Furthermore, the entrepreneur behaved like the leader of the group. Another lab group met with their start-up supervisor only two times during the course. He was part of the management of the company and had not time enough to show up more frequently. But the students understood his limited resources and sent him written reports on their work progress weekly. Nevertheless, all students stated that they were very satisfied with the course and that they had learned a lot.

This can be seen as a hint that – according to the presumptions of Social Identity Theory (SIT) – processes of "generalization" and "accentuation" (Tajfel, 1982) are working within the initiated CoP: Amongst the student "in-group" phenomena of social identification occurred, while between students and entrepreneurs (as "out-group" members) identification is less likely. Therefore, community-building of members of distinct social groups with different cultural and historical experiences faces specific problems of understanding and needs advanced coordination efforts. The economical presumption that the students work for the entrepreneur as a customer, may be an additional barrier for CoP building processes.

The role of the *method change* has to be investigated further on. Extreme programming (XP) was introduced by the course designers to have a method at hand which is known to be more suitable for short projects with small development teams than UML and the unified process. Most of the students were very pleased with the method itself but the difficulties with the applications of all the XP rules were obvious. In case of urgency, students ignored programming principles and returned to "good old hacking" approach. The companies were very interested in the XP approach because their established software engineering methods proved to be even more underdeveloped than in the projects with the students. A CoP-aware software development method is still an open issue. As XP rules demand the on-site customer and team oriented programming, this could be a possible starting point to integrate XP as a software engineering method.

To sum up the interview results, we can see that limited resources (both persons and time), spatial distance, cultural differences, and incommensurable expectations still hinder the establishment of CoP between university students and company practitioners.

CoP within the lab groups

The establishment of a common practice was quite successful within the lab groups since all computer science students showed only *slight differences in their competencies*. All participants underlined that the *close cooperation* in the labs was one of the main learning effects. They expect that the established cooperation and relationship will last longer than the course.

The *group structure* in the project labs was developed self-organized and described as non-hierarchical. Some of the students and one of the tutors stated that it would be better to establish a formal leader of lab groups to draw decisions and coordinate the process. In this regards, the *role of the group supervisors* has to been researched carefully.

One of the major design changes in comparison to the first course was that the groups in the second course had a *distinguished supervisor*. The supervisor was responsible for establishing the contact between the group and the start-up company, for the facilitation of meetings, for the allocation of rooms, lab places, software and books, and for the consultancy of the groups in daily work and around reviews. The implementation of such concepts depends deeply on the changing role of university level supervisors. They are challenged by the intensity of temporal and emotional engagement as well as by the needed professional qualification. By monitoring the three different supervisors we can observe that they understood their role in different ways. For further studies on the interplay between teachers and learners in university CoPs our theoretical setting can be used as a framework.

Training for presentations techniques was introduced as a new module into the course. This was appreciated very much by the students. The social ties between the students in the group and the psychology students developed very intensively. Some of the students turned out to be very good presenters. So, the offering of training for presentation techniques is not only very attractive and sometimes also proved successful for students but also helps in shaping CoP by additional common practice and further identity-building. In the next years we want to have also computer science students from the last years to become mentors for the groups to give new students the opportunity to meet real experts (apprenticeship learning)

Technological support by the cooperation platform

We assumed that group-oriented learning processes can be facilitated by a community system. In our case, the instructors put project relevant learning materials into the community system. Additionally, instructors were electronically available for consultancy and supervision. The lecture series and review meetings supported the reflective processes of the students related to their tasks. Discussions between students, lecturers, and practitioners were intended to be a starting point of learning processes in practice. The course's time schedule contained fixed meetings, review sessions, workshops, and a tentative list of lectures. As a technical infrastructure, a community-system (BSCW) was deployed to the project groups. The system supported cooperation within and between working groups. Lecture and project materials have been published regularly on the net. In order to find these materials, the system offered various options for retrieval. Programming tools like a source code management system (cvs) and various editors have been installed to support community-oriented work settings.

Contrary to the first course, the community system was *used very frequently* by all groups and students. From the beginning of the lab, the instructors enforced the use of the system in the tutorial and the reviews. In the tutorial one of the first tasks was to fill in personal data and to upload a portrait. Therefore, the first use of the system was already manipulative and the barrier to upload and to exchange materials was lowered. In comparable teaching situations, when students are not asked to change information in the system, the use of the system is more passive.

Furthermore, the lab groups were bigger and the start-up practitioners used the system more intense than in the first course. All interviewees evaluated the usage of the community system as *very positively*, in fact we have got the strongest positive reactions referring to the community system and the presentation techniques. Of course the bigger project groups affected the more intense usage of the community system.

The community system was used for up- and download of documents, for discussions in forums, for co-authoring of documents, for annotations, and for awareness information. For planning activities and negotiation on meetings, other media like phone and e-mail were used instead of the cooperation platform.

Interviewees named *some shortcomings* of the system: They missed *features for synchronous communication* like chat. The up- and download of documents was evaluated several times as too complicated.

Furthermore, the *introduction process for the community-system* has to be designed carefully to reach a mission critical use of the system during the course and later on. Barriers in using the system were lowered by the first guided steps to use the system. Consequently, later use was very intensive extending the use of the system far beyond the timeline of the lab course (especially for downloading materials not stored elsewhere like videos taped in the review sessions and personal information about other lab members). Based on the good experiences with the introduction process we have codified the process and use it for a community-oriented continuing education portal.

DISCUSSION

Socio-cultural theories of learning stimulate the design of practice-based courses in computer science. The results of the evaluation have shown that both networking on a technical and a social level offer new opportunities for university level education. Especially the work on real-world problems, collaboration in teams together with partners from start-up companies were evaluated very positive. Following a first instance of the course the didactical design was modified considerably according to evaluation results. By a more precise selection of start-up partners, larger lab teams, coaching of the lab groups by tutors, and increased motivation to use the technical community-system, collaboration and therefore the establishment of a common practice within the lab groups have been encouraged.

The computer support for learning CoP causes new duties and requirements for academic supervisors. Establishing of CoP needs developed *social competences in fostering trust and team spirit*. This observation corresponds with the theoretical assumptions of the social capital approach (cf. Cohen and Prusak, 2001).

Furthermore, additional engagement of students of organization psychology, certain trainings (e.g., presentation techniques), and the conduction of more review meetings, led to a better evaluation of the second instance. In the first instance of the course in 2001, design flaws, cultural as well as professional diversities, and imponderableness of reality limited the success. Although the second instance of the course in winter term 2002 was redesigned, again we did not succeed in establish a common practice between academia and industry within the scope of the course. Most important barriers for the establishment of CoP between university students and start-up companies are limited resources (time and personal) and cultural differences. Especially the differences in cultural background and different historical experiences in the two distinct groups of “students” and “entrepreneurs” might make processes of social identification more difficult and therefore successful community-building less likely. Generalizations within “in-groups” lead to reinforcement of perceived similarities, while accentuation between members of different “out-groups” increase perceived differences (cf. Tajfel 1982). This perception of *intra-group* similarities and *inter-group* differences might hinder the establishment of CoP between members of different group and should be taken into account with regard to the design of supporting conditions for the establishment of communities of practice.

Moreover, according to the social capital approach the establishment of CoP between academia and regional industry depends on a culture of mutual trust (cf Putnam, 1993; Cohen and Prusak, 2001). Therefore, mutual learning of university students and regional company practitioners needs social capital which is built by common experiences and shared practice. So our approach will need more instances to build a sufficient level of trust and social capital in regional networks between university and industry. Both establishment of CoP and building of social capital *need time* to emerge (cf. Lave and Wenger, 1991; Cohen and Prusak, 2001). Thus, the limited time frame of a course taking place during just one single term (3-4 months) limits the opportunities for successful initiation of CoP between students and company practitioners. On the other hand, repetition of the course should establish social capital and CoP between academia and regional industries.

The personal reputation of the supervisors from the university in the entrepreneurial networks has been leveraged by the courses, e.g. they are included into information exchange networks and are invited to start-up related events like business plan competition, and company fairs. In the meantime, many joint supervisions of master thesis work and joint presentations at different fairs document the successful cooperation between local start-up companies and the university. Further development of university structures is needed but also new potential for universities is offered by networking with local industry and life-long learning activities within continuing education. This established cooperation structures and a culture of mutual trust can reinforce the opportunities for further lab course cooperation in the future. Many instances of the course in the following years allow us the do slight modifications in the design of single elements of the course and to study the effects. Nevertheless, good personal relationships and therefore rich social capital was established between *some* students and practitioners. We cannot answer the question, whether self-organized and non-hierarchical structures or the existance of a groupleader would better support the building of social capital within the lab groups. In all lab groups learning mechanisms of legitimate participation have been proved successfully. Especially the students reported on high intensity learning while creating a common practice in the lab groups.

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Towards A Design Framework for Mobile Computer-Supported Collaborative Learning

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Abstract. We present one component of a foundation for mobile, handheld device-supported collaborative learning (mCSCL), a design framework. Our design framework proposes that mediation can occur in two complementary layers, social (e.g. rules and roles) and technological. Further we suggest that for mCSCL, the technological layer has two components, representational mediation and networked mediation. A particular design challenge is achieving an effective allocation of supporting structure to each layer as well as simple, transparent flow between them.

Keywords: CSCL, mobile, handheld, design, collaboration

INTRODUCTION

Mobile, handheld devices are growing in importance in education, in part because they are much more affordable than conventional laptop or desktop computers (Norris & Soloway, 2003). Further, mobile handhelds can easily be used in any classroom or field site; hence they can be used more often than computer labs (Vahey & Crawford, 2002). In addition, students may own these devices and be able to take them home, multiplying their potential utility in the learning process (Consortium for School Networking, 2004). In sum, these devices enable a transition from occasional, supplementary use of computing to frequent, integral use (Roschelle & Pea, 2002).

We focus on two affordances that these devices provide which are closely coupled to learning: (1) dynamic representation (e.g. graphing, simulation, mapping, visualizing, modeling) and (2) classroom-area networking. The use of dynamic representation to enhance what and how students learn has a long track record in educational computing (Roschelle, Pea, Hoadley, Gordin, & Means, 2000). Early experiments suggest the power of dynamic representation can translate well in mobile, handheld-sized screens (Tinker & Krajcik, 2001). Classroom-area networking is a newer concept, focusing on the creation of an information flow topology within classrooms that enhances individual, small group, or full classroom activities that are occurring face-to-face (Roschelle, 2003).

Presently mCSCL is a rapidly growing field with much of its intellectual activity focused on discovering, describing, and documenting the effectiveness of specific designs for using these devices in learning. Relative to these activities, a strong design framework could have three important benefits: (1) developers could use a comprehensive framework to more carefully think though their planned design (2) researchers could use a framework in developing taxonomies, comparisons, and data aggregation across individual projects (3) teachers and students could benefit from a more complete, standard way to describe what they should do.

This paper is organized to argue for a candidate design framework for mCSCL. Starting from a literature review, we develop the idea that core design challenge for collaborative learning is designing activities (or tasks) that artfully align and interrelate content and relationship goals, achieving synergies between the imperatives of human relationships and the imperatives of the educational content. We suggest technology plays two mediating roles: (1) representing content to support student reasoning and (2) coordinating the flow of information in support of collaborative learning. We have deployed our framework to describe eight well-known, successful mCSCL learning activities. Due to space limitations, we cover only two here.

LITERATURE REVIEW

We see mCSCL as nested construct, building first upon research on social constructivism and general research findings on how people learn, second upon foundations of collaborative learning and CSCL, and third upon the new affordances unique to this technology.

Social Constructivism

According to Johnson & Johnson (1987), classroom learning improves significantly when students participate socially. Research on constructivist learning environments has shown that children see their classmates as a source of knowledge and help, rather than as a competition. Social cognition creates knowledge and skills in the context of use (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991).

Social constructivism suggests five principles for an educational activity (Newman, Griffin, & Cole, 1989). Educational activities should be:

1. Constructive: existing student knowledge schemes are integrated with new information to acquire new knowledge.
2. Active: each child is expected to participate in generating new knowledge and learning from peers.
3. Significant: learning has to be personally meaningful to the student.
4. Reflexive: the group acts as a mirror for each student's learning process.
5. Collaborative: where the student learn with the other members of a group, the group has the same pedagogical goal, and each member is a potential source of information.

The childrens' experience and knowledge, mutual feedback, and their own and shared reflection allows them to build their answer as a group constructive (Roschelle & Teasley, 1995). Students are encouraged to explain their findings, i.e., the meaning of words (reflexive). The children contribute with their ideas and knowledge socially, interacting and negotiating possible concepts (based on consultation). Finally, every child's contribution should be shown to the other children within the group in a common space (significant, reflexive and collaborative) (Zurita & Nussbaum, 2004).

How People Learn

The foundations of social constructivism resonate with accumulated evidence from the Learning Sciences, as synthesized in the book, *How People Learn* (National Research Council, 1999). Research spanning multiple ages and subject matters suggest that Students come to school with prior knowledge that strongly effects how they learn new subject matter. If this incoming knowledge is not engaged in the course of instruction, students frequently fail to learn desired subject matter concepts. To develop competence in a subject matter, students need to learn facts in relationship to a conceptual structure that organizes their understanding and use of the subject matter. Conceptual understanding is an essential goal for instruction. Teaching should aim to encourage students to be more active in taking control, monitor, and regulate their own learning. Learning strategies are not generic across subject matters, and treating them as generic can lead to failure. Thus such "metacognitive" emphases can and should be integrated into subject matter teaching.

Collaborative Learning

Collaborative or cooperative learning seeks to use small groups for instructional purposes in such a way that students work together to maximize their own learning and the learning of others (Johnson, Johnson & Smith, 1991; Cohen, 1994). In order to achieve collaboration, it is essential that the activity include: opportunities for face-to-face interaction; joint attention to ideas or materials, positive interdependence (each students' contribution is needed for the group to succeed), individual responsibility, interpersonal and small group skills, and group processing (Johnson, Johnson & Smith, 1991; Holubec, 1999; Cohen, 1994, Barron, 2003). When these essential features are present and the above additional considerations are addressed, collaborative learning can produce strong student motivation and achievement.

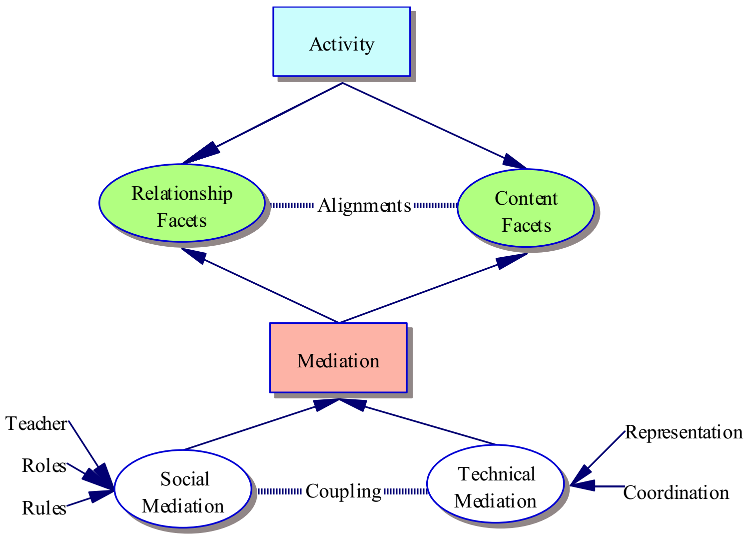
In collaborative learning activities, there is both content to be learned and a relationship between group members that has to be sustained. "Collaboration might productively be thought of as involving a dual-problem space that participants must simultaneously attend to and develop a content space and a relational space (consisting of the interactional challenges and opportunities)" (Barron, 2003, pp. 310). The content space can be defined by the proposals generated by the members about the given content. The relational space is defined as the joint attention to those proposals. According to Barron, more successful groups respond by accepting or discussing the proposals, whereas less successful groups have a high probability of rejecting or ignoring the proposals. According to Dillenbourg (1999), an educational collaborative activity can be successful when there is: (a) a well-defined objective, (b) regulation through rules and roles, (c) a defined domain consisting of the number of group members, the criteria for the group composition, and the specification of the technological mediation, and (d) an adequate environment for the educational context.

mCSCL

Wireless communications are particularly conducive to the sharing and comparing of information and results whenever students work in groups (Vahey & Crawford, 2002). While collaborative learning based on laptop-type computers makes students focus their attention on spaces which are fully contained within the limits of the screen, handhelds increase the space available in exchanges of information (Roschelle & Pea, 2002). Simultaneous interconnection makes the students more active and engaged in the learning process (Inkpen, Mandryk & Scott, 2000; Inkpen, Ho-Ching, Kuederle, Scott & Shoemaker, 1999). mCSCL applications can:

organize the managed information, provide a negotiation space, encourage coordination between the activity states, and mediate synchronization and interactivity, (Zurita & Nussbaum, 2004).

OUR PROPOSED FRAMEWORK



The root construct of our proposed framework is an activity or task—a coherent, planned process that is intended to facilitate a large group of students making significant progress in learning particular content in a bounded time and space. Activities could be more elaborately rendered via Activity Theory (Nardi, 1996) or more simply rendered as lesson plans. Within an activity, the design should encompass two important facets: relationship facets and content facets .

The **relationship facets** of an activity design should describe how the human imperatives of face to face learning will be addressed. Relationship facets include joint attention, group processing, individual responsibility, positive interdependence, and social skills, as described in our literature review above. One of the *How People Learn* constructs, community-centeredness, fits here as well. The **content facets** of an activity design should describe how the subject matter imperatives of face to face learning will be addressed. These facets include learner-centeredness, knowledge-centeredness and assessment-centeredness.

An mCSCL activity cannot be simply simultaneously social and contentful—the social and content facets must be mutually supporting.. The prior literature provides theoretical constructs that may prove useful for giving reason to the **alignment of social and content facets** (e.g., social activity may increase cognitive conflict, leading to pressure to transform conceptual schemes to accommodate new ideas).

Social learning activities do not happen just because they are planned, nor are they necessarily easy to carry out productively. A major focus in design, therefore, is to specify appropriate mediational means to ameliorate expected troubles or activate latent potentials. **Mediation** can be social or technical. In any given mCSCL, both are likely to be employed.

Social mediation may be provided by specifying guidelines for the teacher, roles for students, or rules for their joint work. The teacher may be asked to motivate or instruct the students, coach students on social skills, monitor the process of the activity and make adjustments to facilitate progress, and provide helpful feedback.

Technological mediation, first of all, may be paper-based. The activity designer, for instance, might right rules or roles on paper. Given the small screens of mCSCL devices, paper can dramatically expand the space available to a designer for structuring an activity. Within uses of the devices themselves, we see mediation as broadly representational or broadly coordinative. For example, a graph that controls an animation may be a powerful representation for learning mathematics. Coordinative mediation provides ways of organizing the flow of information among mCSCL devices to support the objectives of the activity. For example, aggregating a set of students answers but only allowing the students to see whether they all agreed or they differed may support the objective of an activity.

It is to be expected that some of the activity will be mediated technically and some will be mediated socially. Thus it is critical, if the activity is to succeed, for the designer to attend to how these two channels are coupled. How for instance can the student talk about "my idea" when it has been transmitted to another students' device and incorporated into their representation? Likewise, if some important part of the activity is occurring socially, how does the technology become aware of what has happened? Commonly, shared reference to technologically mediated learning may be accomplished by the use of a large, public display.

TWO ILLUSTRATIONS OF USING THE FRAMEWORK

Match My Graph

"Match my graph" (MMG) uses Palm handhelds with infrared beaming to engage students in refining their ability to use concise mathematical vocabulary to describe linear functions. The content facet of MMG involves translating between graphical and linguistic definitions of functions. Students have great difficult describing how linear functions differ; where a mathematician would use terms like “slope” and “y-intercept”, students may see a graphed function as “short” or “jaggy.” The student descriptions may reflect artifacts of the computer screen than an expert would ignore and the students may ignore the very features an expert finds most salient. The relationship facet of MMG is patterned on the popular game “mastermind” – one student has a secret which the other student tries to guess. If a guess is wrong, the secret-holder provides a hint. Social and content facets are aligned in MMG because the “secret” is a graph that the other student cannot see. Hints are given linguistically; to solve the challenge students must translate the features of their graphed function into a verbal hint, and the other student must translate the hint back into a new graph. The social and content aspects of MMG are aligned because the game motivates students to develop clearer ways of talking about linear functions.

Mediation in MMG is both technical and social. Students sometime have no idea about what kinds of hints they might try. The technical mediation is both representational and coordinative. The representational aspect involves the use of the stylus and the Palm’s graphic display to make it easier to sketch and manipulate graphs of linear functions. Because the Palms are small and personal, students can easily hide their “secret” by holding their screen vertically. The Palm also supports coordinative mediation: a student beams a guess to the secret-holder. When the guess is received, the secret-holder can see both functions on one graph. This facilitates comparison between the secret and the guess. Hints, however, are given verbally – not through the technology. Further, teachers mediate hint-giving by coaching students, again socially without technical mediation. The technical and social mediation is linked by consistently color-coding a player’s function. This makes it easy to talk about a particular function, e.g. “your red function” vs. “my blue function.” After students play MMG several times, the teacher engages the students in a group discussion. The purpose of the group discussion is to reflect on the different ways of describing functions that each student used and on the nature of clear mathematical communication.

Collaborative Construction

The goal of a collaborative construction activity is for students to assemble a creative object from the unique component pieces each student holds. In one simple example, “Silaba,” each student receives a syllable (Figure 2). Students work together to assemble their syllables into words (Figure 2). A group of three members is defined (Dillenbourg 1999, Zurita & Nussbaum 2004a). Each child receives an element, i.e. a different syllable. In Figure 2, Miguel receives “si”, Gustavo “la” and Rodrigo ”si”. The children have to find out the correct combination of syllables. For the example, the possible combination is “silaba”, “bala”, “la” and “si”. (In Spanish unlike English several words can be built from a set of syllables).

(a) (b) (c) (d) (e)

Figure 2: Collaborative Construction application; construction of words

We analyze the Relationship Facets following the Social Constructivism principles. The children previous knowledge, mutual feedback, and own and shared reflection allows them to build as a group their answer (constructive). They are encouraged by the teacher to explain their findings, i.e., the words meaning (reflexive). The children contribute with their ideas and knowledge socially, interacting and negotiating possible words (based on consultation). Finally, every child contribution is shown to the other children within the group in a common space (significant, reflexive and collaborative). For example, Miguel selects his syllabus, the machine shows the syllabus to him (Fig 2d) and the other members (for example Rodrigo, Fig 2e) in their corresponding screen and tells also Miguel that he has now to wait for his partners.

The cognitive effort is targeted to the collaborative construction activity. All the necessary information and a structured decision-making procedure is given through the handhelds. The handhelds network provides a negotiation space that encourages coordination between the three activity states. Each child decides how his syllable is used, i.e. when his turn is in relation to the rest of the group, allowing collaborative discussion on the construction procedure, mediating the handhelds synchronization among the members.

Finally we have the role of technology, i.e., representation and coordination. This includes assignment of tasks; within each group, each member receives his own syllable. Since the syllable is only available to one member, s/he has to inform the other members, providing interdependence and interactivity within the group. In terms of representation, the screens provide a space for sharing the current state of the group construction. In Figure 2c, 2d, and 2e Miguel and Rodrigo share what Miguel did. Since the word is constructed simultaneously on all screens, the technology provides a visual negotiation space. Technology forces synchronicity blocking the child that already chose his her syllable.

CONCLUSION

Mobile, handheld, wireless devices are opening new possibilities for collaborative learning. As interest in mCSCL grows, researchers, developers, and teachers will look for ways to organize, analyze, and synthesize resulting knowledge. We suggest that articulating a design framework that potential spans many mCSCL activities can contribute the foundations of further work in this area.

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Implementing Online Collaborative Professional Development for Innovative Educators

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Abstract. The purpose of this study was to describe how four teachers in different cities in Missouri implemented an innovation cluster that paired an online technology with a problem-based unit design framework. The motivating principle for the study originated from prior research on teacher adoption of technology innovations and principles of professional development for educators. Using a multiple case study research method, the researchers collected and analyzed data to (1) understand how effectively the teachers implemented the unit while participating in online collaborative professional development and (2) identify cross-case issues that arose as the teachers collaboratively implemented the problem-based unit.

Keywords: Guidelines, formatting instructions, author's kit, conference publications

OBJECTIVES AND PURPOSES

The purpose of this study was to understand how teachers participate in collaborative online professional development in order to implement an innovation cluster that included emerging online technologies and a framework for a constructivist-based learning environment. The researchers focused on three progressive issues that emerged during in vivo data structuring: (1) what factors in a teacher's school environments influence the implementation of an innovation cluster? (2) how does a teacher's participation in collaborative professional development influence the implementation of an innovation cluster? (3) how does a teacher's belief about learning and technology influence the implementation of an innovation cluster?

We used Activity Theory's concept of development of object in order to identify the work activity model of each teacher's classroom practice. We designed and categorized each teacher's AT model based on initial pre-unit interviews. We then identified the teacher's responses to contradictions, pressures within their work activity settings that arose during the implementation of the unit. We further defined the response of the teachers to these contradictions as turning points, changes in activity in their classroom. We then evaluated these turning point responses as resulting in 1) a resolution of the contradiction thereby widening of the teacher's object or 2) a response which did not resolve the contradiction resulting in narrowing of their object. Next we identified the cross-case issues that developed over time among the teachers in order to evaluate the effectiveness of the online collaboration that was the only collaborative professional development available to the teachers as they simultaneously implemented an online problem-based unit in their classrooms. As a result of this systemic and contextual identification of contradictions and the focus on three progressive issues in order to clarify the inter-relationships of these responses to the development of the object, we were able to identify the important influences that affected the effectiveness of the online professional development program in responding to contradictions in their work activity.

Theoretical framework

The theoretical grounding for this study was sociocultural theory of human interaction, and development (Vygotsky, 1978; Bruner, 1990) with an emphasis on understanding the processes of mediated activity (Wertsch, 1998). The researchers used Activity Theory, (Engeström, Miettinen & Punamaki, 1999; Il'enkov, 1977) in order to design a systems framework for understanding the implementation processes in context and over time. Activity Theory defines the elements of human interactions in a work activity setting and was used by the researchers to design analytical procedures that developed systemic and contextual relationships among the dataset (Engeström, 1987; Barab, Hay & Yamagata-Lynch, 2001; Schoenfeld, 1999). Using this systems-based methodology, the researchers studied the interactions of the constituents of the system that produce behavior (Aronson, 2003) and developed explanations that link the components as a "consilience of inductions" (Wilson, 1998, pg. 98). The compelling purpose of complex systems analysis is to recognize the organizing relationships between entities in the system from which emerge the unique properties of the systems (Banathy, 1991). This form of analysis provides contextually valid responses to complex social systems by making the interactions in the system explicit so practical and theoretical implications can be developed. The overarching premise for this form of analysis was that the nature of human development is socially embedded and fundamentally activity oriented resulting in an anticipated outcome (Cole & Engeström, 1993).

This research studies the online professional development of four k-12 teachers that implemented a collaborative online problem-based unit. The unit involved an introduction of two new tools, an online technology and a problem-based unit of study design template, into the classrooms. We defined the insertion of these two co-dependent tools as an innovation cluster. The insertion of new tools mediates the action of the agent (Wertsch, 1998). In this case study analysis the agents are the teachers. New tools contain both affordances and constraints that insert a source of tension into a work activity system identified as contradictions. We used previous research to define the relationship among the AT aspects of the implementation of this unit including studies of innovation (Rogers, 1995; Hall, Wallace, & Dossett, 1973; Wilson, Sherry, Dobrovolny, Batty, & Ryder, 2001) and collaborative design and implementation of a constructivist-based learning environment (Jonassen, 2000; Savery & Duffy, 1996; Lave & Wenger, 1991; Schank, 1994; Salomon, 1993) and identify the resulting contradictions in the work activity of these innovative teachers.

The object of an activity system is something given and something anticipated. In this study, the initial goal for the educators involved collaboratively implementing the problem-based unit and incorporating the online workspace so their students can work together online to problem-solve. Using Activity Theory (AT) to define the constituent components, nodes, of the work activity of the teachers, the researchers used N*UDIST software to structure the nodes of the AT model (e.g., motive, goal, subject, mediation, object, community, rules, division of labor, outcome) and integrated the theoretical constructs from related fields (e.g., professional development, innovation, collaboration) into operational categories of interactions in the work activity of the teachers. The researchers identified the contradictions in each teacher's work activity, structured around the three progressive issues. We then focused on defining the turning points resulting from these contradictions as teacher behaviors during the implementation of the unit in their classrooms and finally we evaluated these resulting turning point behaviors as resulting in a type of reformulation of the teachers' objects, such as widening, narrowing or disintegrating their object. Finally, the researchers also identified cross-case patterns of responses among all four teachers using the progressive issues that arose in vivo to clarify the relationships and develop conclusions concerning the four teachers' professional development responses. As a result, the researchers were able to describe the online collaborative professional development processes of the teachers and how they impacted their implementation of the advanced problem-based unit of study using online technology.

METHODS

Setting

The researchers studied four elementary teachers who work with students in 4^{th} and 5^{th} grades in four different cities throughout Missouri who were implementing a collaborative online problem-based unit during the final quarter of the 2001-2002 school year. The students represented inner city, small city, suburban and rural students. All the teachers had computer labs in their classrooms as a result of their participation in eMINTS (enhancing Missouri's Instructional Networked Teaching Strategies). eMINTS is an technology integration program developed by Missouri's Department of Elementary and Secondary Education (DESE). It establishes classroom computer labs in order to illustrate the use of technology in classroom instruction and trains teachers in constructivist-based instruction. Because of their involvement in the eMINTs program, the teachers that participated in this study had the same prior amount of technology and inquiry-based learning training, 3 years, and the same amount of hardware and software in their classrooms. The classroom settings are depicted in Table 1 below.

These four eMINTS teachers were invited to participate in an online pilot project with MOREnet (Missouri Research and Education Network) called the Pioneers Program. The teachers volunteered to implement a new Linux-based middleware, Shadow netWorkspace™ (SNS), and collaboratively develop and implement a problem-based unit that incorporates constructivist-based learning methods and takes advantage of the many affordances of SNS. SNS was provided free to their classrooms through the University of Missouri at Columbia's College of Education as part of the School of Information Sciences and Learning Technologies. SNS provided the teachers and the students with online workspaces where they could dialog in synchronous and asynchronous forums and work on creating and disseminating artifacts. The researchers designed professional development interactions among the teachers including an initial phone conference, multiple weekly chats, and an online reflection journal. Throughout the implementation of the new unit, teachers' only collaborative professional dialogs were in the seven weekly online chat rooms.

The unit that the teachers volunteered to implement was an authentic design-based problem solving unit titled "Improving I-70". The researchers created a unit design template which was used by the teachers to develop their individual and collaborative problem-based unit. The problem addressed by the students was the repair of Interstate 70 which runs across the state of Missouri. Each classroom worked collaboratively online with students in the other classrooms to design a response to the state-wide problem from the multiple perspectives of students in a rural, urban, suburban and small city setting. The unit was designed to be implemented in three phases. In Phase 1 the students worked in their local classrooms developing the problem background. In Phase 2 the students worked in online SNS workgroups to understand different areas of expertise involved in solving the problem. In Phase 3 the students worked back in their local classrooms to develop strategies to solve the problem. The purpose of the collaborative online problem-based unit was for the students to develop problem-solving abilities with multiple perspectives.

Table 1: Classroom Descriptors

<table>
<tr><th></th><th>Grade</th><th>Community</th><th>Students</th><th>Technology Access</th></tr>
<tr><td>Linda</td><td>4th</td><td>suburban</td><td>12 boys and 10 girls, all Caucasian</td><td rowspan="4">As a part of their participation in the eMINTS program, each teacher has 12-14 Pentium3 LCD computers, a teacher workstation, laptop, a Smartboard and projector, a scanner, a color printer, and a digital camera.</td></tr>
<tr><td>Helen</td><td>4th</td><td>rural</td><td>12 boys and 12 girls, all Caucasian</td></tr>
<tr><td>Janice</td><td>5th</td><td>urban</td><td>7 boys and 10 girls, all Black or African-American</td></tr>
<tr><td>Carol</td><td>4th</td><td>mid-size city</td><td>9 boys, 10 girls; 11 Caucasian, 8 Black or African-American</td></tr>
</table>

Findings

The data collection process used interpretive research practices (Fraenkel & Wallen, 1996) to capture the dynamics and complexity of the teachers' online professional development throughout implementation of the unit (before, during, and after implementing the unit). The goal of data collection was to capture aspects of the implementation and identify the influence of the online professional development in a way that enables the researchers to fully realize its complexity and make it available for contextual analysis and evaluation. The data collected from the teachers included initial and follow-up interviews, transcripts from a phone conference and seven chatroom conferences, messages posted on discussion boards, reflective questionnaires related to their design of the unit and the principles of constructivist learning, an online journal, and documents the teachers produced related to the unit and technology.

Each teacher's transformative processes were analyzed through the identification of contradictions using activity theory. Secondary contradictions were identified in each individual teacher's activity setting. These contextual contradictions defined the progressive issue, what factors in individual teacher's school environments influenced the implementation of an innovation cluster? The researchers designed an AT teacher model for each teacher to illustrate secondary contradictions. An example of a teacher's post-unit AT model is shown as Figure 1 below. Contradictions unresolved are shown as solid broken lines in AT Model. Resolved contradictions are shown as dashed broken lines. The top of the triangle depicts the new tools inserted into the activity system of each teacher which included the new problem-based unit, Improving I-70 and SNS. The middle of the triangle shows the subject, the names are pseudonyms, and the object, the implementation of the problem-based unit using SNS with the teacher's initial anticipated outcome for the activity, the potential to develop advanced problem-solving skills including multiple perspectives in their students. The bottom of the triangle depicts the contextual issues such as rules in the context, school or district, community, and division of labor, those necessary to the implementation. The factors listed in each category were assigned after initial interviews with the teachers.

A tertiary contradiction occurs between interacting activity systems. This type of contradiction was a response to the second progressive issue, how does a teacher's participation in collaborative professional development influence the implementation of an innovation cluster? This type of contradiction occurred when the teachers collaborated to define a common object during their weekly online chats. The researchers coded the teachers' online dialogs to define the dialogic turning points as text instances when the teachers redefined their object and changed an aspect of their implementation in their classrooms (Kärkkäinen, 1999). A dialogic turning point is an event when a teacher or the teachers began to outline their object in a different way. The signifiers of turning points can be a questioning of an established practice or concept, an aspect of a multi-voicedness of the collaborative processes and a change in emphasis in the sequencing of the dialog. These aspects of the identification of turning points in the reformulation of object are described by Virkkunen (cited in Käkkäinen, 1999) and are based on Leont'ev's concept of object, Halliday's theory of register (Wells, 1999) and Bakhtin's concept of voice (Bakhtin, 1982).

We operationalized the concept of dialogic turning points using three indicators of transformation: disturbance clusters, questioning, and interaction of different voices. The first indicator of change was the appearance of disturbance clusters, namely clusters of dilemmas, disturbances, and innovation attempts of team discourse. Halliday's concept of register focuses on the identification of patterns in social dialog. Dialogic turning points were identified as breaks from this pattern of exchange. The second indicator was questioning. A part of the transformational process was questioning of the ideas and accepted practice. The researchers located points of change by identifying questioning episodes in the dialog of the teachers indicating a change in the formulation of the object. The last indicator of dialogic turning points used in the study was the concept of multi-voicedness. This concept is based on Bahktin's theory of genre in social language. The multiple voices of the teachers during their dialogs throughout the design and implementation of the unit introduced variations in their concepts of the pedagogy of reform and perceived attributes of the innovation cluster.

A primary contradiction defines the relationship between motive and outcome. A primary contradiction is as negative tension between the concepts underlying the implementation of the object. This type of contradiction defined the progressive issue, how do individual teacher's beliefs about learning and technology influence the implementation of an innovation cluster? In this study the teacher's pre-unit motive for implementing the innovation cluster was defined as the potential to develop advanced problem-solving abilities in the students with awareness of multiple perspectives in problem-solving. The researchers identified changes in motive and outcome relationships by the teachers in response to work-related pressures. The researchers coded the teachers' concept of the learning processes potentially available as a result of developing their object, the implementation of the unit, as hierarchical levels of the teacher's philosophy of learning using Bereiter's Scheme of Knowledge (Bereiter, 2002).

Case Study Conclusions

Linda's final Activity Theory model is shown below as Figure 1. Linda is a suburban teacher that has developed innovative units previously and was very supportive of the goals for the I-70 unit. In her pre-unit interview she stated her goals for her students for implementing this unit as the development of problem-solving skills with multiple perspectives. Linda experienced three contradictions during implementation of the unit. She resolved one and two were unresolved. She overall narrowed her object in-depth because, although she completed the entire unit, she did not implement Phase 2 online with the other classes which prevented her students from studying the problem with the perspective of the other classes. Pre-unit she described her local work environment as very collaborative and supportive of reform efforts. Prior to beginning the unit, she resolved a contradiction in her local work environment between rules and subject when she changed her schedule so she would not be departmentalized during the unit.

Both of her unresolved contradictions were related to the mediational tools that she added to her classroom practice, the I-70 Unit and SNS. The tool to subject contradiction shown below was between the learning potential of the problem-based unit and her beliefs about student learning. It was identified during the post-unit interview when she said that she would not again implement an authentic problem-based unit such as Improving I-70 because it did not deliver enough content for standardized testing. Her original stated motive for implementing the unit, to develop problem-solving abilities with awareness of multiple-perspectives, was coded as a Level 5 learning response using Bereiter's Scheme of Knowledge. However, her post-unit subject concept of delivering content in order to prepare students to take a standardized test was coded as a Level 2 knowledge response. The unresolved tool to object contradiction was identified in her online dialogs. During Phase 2 when all the students worked online in groups, Linda expressed discomfort with the student online chats describing them as "chaotic." When she decided to take her students off the internet so she could finish the unit in her classroom where she was more comfortable with the learning activities, she prevented them from studying a problem from multiple perspectives. This contradiction between her beliefs about learning and the problem-based unit was not resolved as a result of her online professional development processes.

She did not resolve either contradiction as a result of the online professional development. She did not contact either researcher for help during the unit. She had experienced inquiry-based learning units prior to the development of this problem-based unit. However, she had not previously worked in open-ended problem-solving problems with her students. Her inert contradictory concepts of how this unit would progress in her classroom and how her students would respond in the unit's online activities were not identified and addressed in the online professional development process.

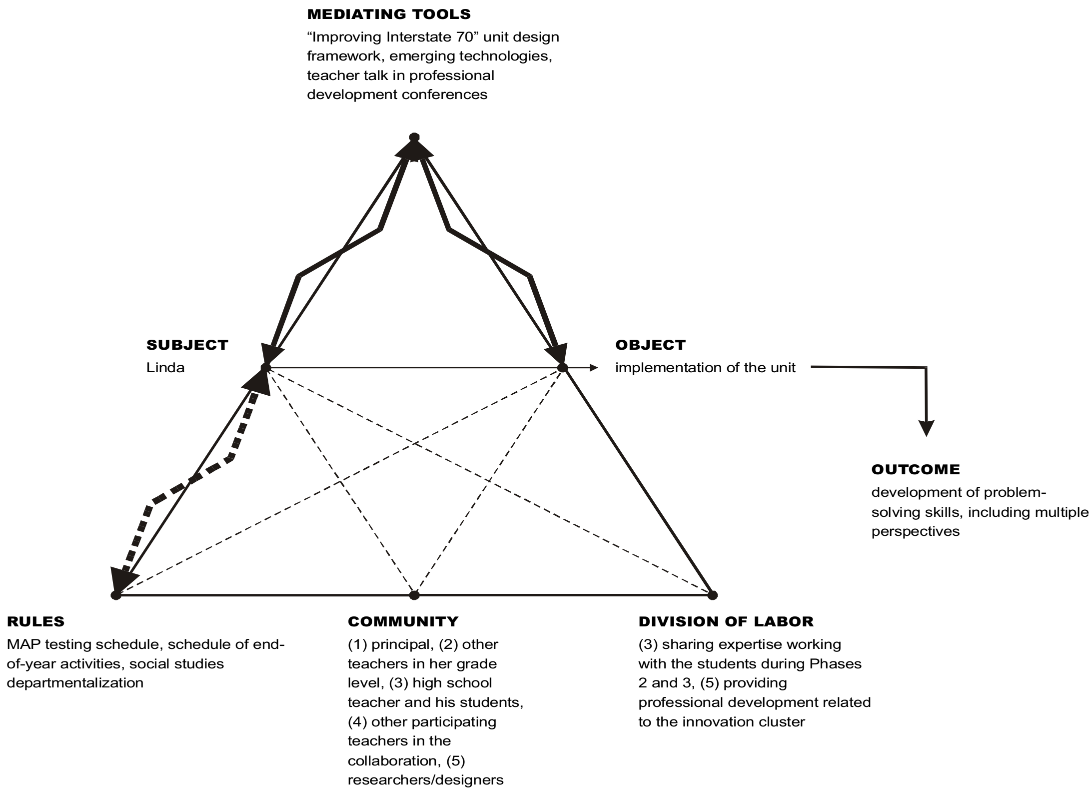

Figure 1: Linda’s Final Activity Theory Model

Helen, the rural teacher, experienced two contradictions, both unresolved, and overall disintegrated her object by ending her unit early. In her pre-unit interview she was very supportive of the new online tool and the unit goals. Pre-unit she described her local context as collaborative and supportive. However, she did not describe her technology support person as supportive. Her contradictions both occurred as context-related problems. Helen had an unresolved contradiction between object and division of labor. Her technology support person added a filter to her local server during the unit and she was off-line for over a week during the unit. She did not talk to him about her sudden loss of the internet and, as a result, her students lost valuable online collaboration time during the unit. The second unresolved contradiction was between community and object. Prior to the unit in an online chat with the other teachers, she agreed to a shortened schedule for her unit even though her rural school ended the school year earlier than the others. Eventually she ran out of time to implement the unit and disintegrated her object. As a result of her online professional development, Helen lessened her ability to implement her unit goals. Helen did not effectively communicate about her unit goals and technology needs. This limited her potential to resolve contradictions.

Janice, the urban teacher, experienced four contradictions, two resolved and two unresolved, and overall widened her object in depth by adding new learning experiences to her unit. Prior to the unit, Janice did not expect her students to successfully communicate online with the other students. She felt they would not be able to type a coherent sentence. In her urban district she was under a lot of pressure to raise student test scores. She only volunteered for this collaborative unit because she felt pressure from the district to use her eMINTS technology in innovative ways. She described her local context as non-collaborative and not supportive of innovation. The two unresolved contradictions were both related to local context issues including the continuing of departmentalization in her school throughout the unit, rules, and problems with her local server, division of labor. She did not dialog within her school with either the other teachers or her principal to end departmentalization or with her technology support person. This limited her ability to resolve contradictions related to context.

However, during the course of the unit she was open to all professional development processes outside the school available to her. She worked very collaboratively online resolving two contradictions related to her object by adding new activities as a result of dialoging online with the other teachers. She developed her urban community resources by asking an engineer to come in each week and work with her students. She also asked the local researcher to come into her classroom and work with her. As the unit progressed she found her urban students to be very successful at problem-solving and interacting online with the other students. As a result of her students' success in the unit, she radically changed how she thought about the learning potential of her urban students and resolved the primary subject contradiction between her beliefs about the learning and the development of her object. In her post-unit interview she said she was planning more problem-based units for her students in the future. She stated that she "would never teach long-division for six weeks again." Her openness to professional development helped her overcome contradictions between her beliefs about the learning of her students and the implementation of a problem-based unit despite the pressure to prepare her urban students to take a standardized test and her perception of her school and district as not being supportive of innovation.

Carol, the small city teacher, experienced four contradictions; two resolved and unresolved, and overall widened her object temporally by increasing the length of the unit and adding more activities. In her pre-unit interview, Carol stated that she did not want to do the entire unit. She only wanted to do Phase 1 and use SNS in her own classroom. She stated that Phase 2 and Phase 3, which included the online collaborations and the more advanced problem-solving processes, were "useless" and too difficult for her students. She stated that she did not work collaboratively with other teachers in her local context calling the process "lock-step" teaching. She volunteered for the unit in order to get SNS into her classroom. Nevertheless, she eventually completed Phase 2 and 3 so she could work with the other teachers. In her post-unit interview she said she did not want to stop the unit because it would she did not want to "let down" the other teachers. She also benefited from the online professional development by adding new activities as a result of the dialogs. However, unlike Janice, in her post unit interview she again stated that she did not believe that the collaboration phase or the problem-solving phase of the unit were beneficial to her students. The online professional development did not help her resolve this contradiction between her learning beliefs and the object of her work activity.

Cross-Case Conclusions

In order to look for patterns among all four teachers, the researchers designed a Transformation Model, figure 2 below, that shows the AT models for each teacher, the turning points and when these turning points occurred during the unit. The Transformation Model shows the AT Models of the teachers pre-unit and during each of the three phases of the unit. A TP in the transformation model represents the teacher's response to a contradiction in relation to the phase of the unit. The turning points are shown on the line going through the AT triangles. The line widens or narrows dependent upon whether the TP resulted in a widening or a narrowing of the object. The final AT model for each teacher is show inside the circle. This Transformation Model graphically depicts the contradictions that arose during the implementation of the unit and how the teachers' responded to the problems. This model aided the researchers in the identification of patterns of responses among all the teachers over the course of the unit. It also allowed the researchers to identify the types of online professional development that were effective or ineffective in aiding the teachers in meeting their goals.

Using the transformation model, the researchers found that all the teachers narrowed their object during Phase 2 when all their students were online in synchronous chat rooms. In all cases, the teachers' responses to the contradictions that occurred during this critical phase of the unit were to use SNS less or not at all. Without SNS the students could not interact with other students throughout the state and understand the problem from multiple perspectives. The collaborative professional development process available to the teachers, a weekly online chat, was insufficient to help these teachers in resolving contradictions, especially critical technology-based contradictions, during this phase.

Two teachers, Janice and Carol, benefited from the online collaboration. Both of these teachers decided as a result of the online professional development to develop new lessons or extend the unit. In their initial interviews both had described their local context as not collaborative. Both Linda and Helen described their context as collaborative prior to the initiation of the unit. During the unit, Linda did not make any decisions that developed her unit or solved any contradictions. Helen made a decision online to delay the initiation of her unit that lessened her ability to implement the unit as she planned. This decision led to her ultimately having to stop the unit during Phase 2. The online professional development was beneficial only to the two teachers who stated pre-unit that they did not work collaboratively in their local context.

There were three belief turning points among the four teachers. Two resulted in a narrowing of the object. One teacher, the urban teacher, changed her beliefs about the potential of her students as a result of working collaboratively with the other teachers and the researchers. Janice identified and resolved the primary contradiction between what she believed her urban students could potentially do and how the unit could develop their potential. Janice developed all professional development processes available to her including, but not limited to, the online professional development. The other two teachers, Linda and Carol, did not identify or resolve their primary belief contradictions as a result of the online professional development. Carol did implement the entire unit despite her belief that the unit was too difficult and useless to her students because she wanted to continue to work with the other teachers. Linda cut short her students' online interactions because she could not reconcile their online problem-solving activities with her concepts of learning activities.

In response to the first progressive issue, what factors in a teacher's school environments influence the implementation of an innovation cluster, teachers who are implementing innovation need problem-solving professional development programs that allow them to resolve the potential contradictions that will occur in their local activity setting as a result of implementing change. Anticipatory problem-solving and the definition of productive communication structures are beneficial constructs for online professional development models of teachers implementing innovation. These teachers used the online professional development program to share information and schedule events but they also needed the online forum to aid them in developing supportive structures in anticipation of problems, especially technology-based problems, which arise when implementing technology-based learning environments.

In response to the second issue, how does a teacher's participation in collaborative professional development influence the implementation of an innovation cluster, the researchers found that the two teachers who described their local contexts as not collaborative benefited, they resolved contradictions, as a result of their chat room dialogs. However, the two teachers who said they were already working at a high level of collaboration locally did not benefit and one even reduced the effectiveness of their reform efforts as a result of decisions made during the collaborative chat room dialogs. Collaborative online processes should be modified to fit the level of previous collaboration and innovation of the participating teachers. Teachers that are isolated in their local context can be more effective implementing innovative as a result of sharing information online with other innovators. However, teachers who are already innovative and working collaboratively need an online professional development program that will develop their reform capabilities more fully by integrating dialogs with experts, mentors or other innovative educators that are working at the same or a higher level of innovation.

In response to the third issue, how does a teacher's belief about learning and technology influence the implementation of an innovation cluster, teachers implementing reform-based units designed to develop advanced learning processes in their students can have primary contradictions between their beliefs about learning and the instructional processes required for practical implementation of the innovative tools that they bring into their classroom. When confronted with a contradiction between their motive and the practice none of the teachers overcame primary-based contradiction with only a weekly chat as their professional development program. Previous studies have identified effective reform-based processes in professional development in education (Korthagen, 1993; Shulman, 1986; Schön, 1983; Lieberman, 1997). These studies have identified the importance of collaborative professional development for teachers implementing reform that involve both advancement of the teachers' understanding of inert (gestalt) cognitive theories (episteme) as well as the development of the practical (phronesis) instructional design aspects necessary to implement units based on these theories (Korthagen, 1993). Online professional development programs for innovators should include multiple forums allowing teachers to dialog in private and public concerning their beliefs about the types of constructivist-based learning processes and activities that they are developing in their classrooms. These processes should occur prior to the implementation of reform and during the implementation process. For example, field-based case study analysis where teachers view and then dialog with other teachers implementing similar levels of constructivist-based learning environments can help highly innovative teachers understand and make overt their underlying beliefs in order to identify and resolve primary contradictions. Innovators in education require a different quality and form of professional development programs to be successful. The design of professional development programs should include processes that help innovators in education problem-solve, proactively communicate their goals and needs and develop coherent mental models of the classrooms that they are developing.

Innovation in education can be a sporadic process as teachers respond to pressures to use new technologies and correspondingly attempt to incorporate new understandings about learning emerging from research in cognitive science. However as teachers attempt to reconcile these new understandings about human learning processes and the addition of these new technologies into educational processes there are no assurances that the two will be compatibly linked and utilized for the development of knowledge needed by students participating in a post-industrialist, knowledge-based, technology infused modern society (Bereiter, 2002). When teachers attempt to implement a technology innovation, they naturally face the complex challenge of fitting together new ideas with deep-rooted beliefs and practices. As a result, teachers often introduce an innovation in ways that reflect a negotiation between old and new ways of doing things (Bruce, Peyton, & Batson, 1993; Bruce & Peyton, 1990) and they may not have adequate professional development to reconcile these tensions with their goals for implementing innovation into their classrooms. As a result, there is an imperative to develop new understandings concerning effective professional development programs for innovative teachers implementing cognitive-based reforms that are anchored in the concept of developing knowledge workers for a technologically-advanced society.

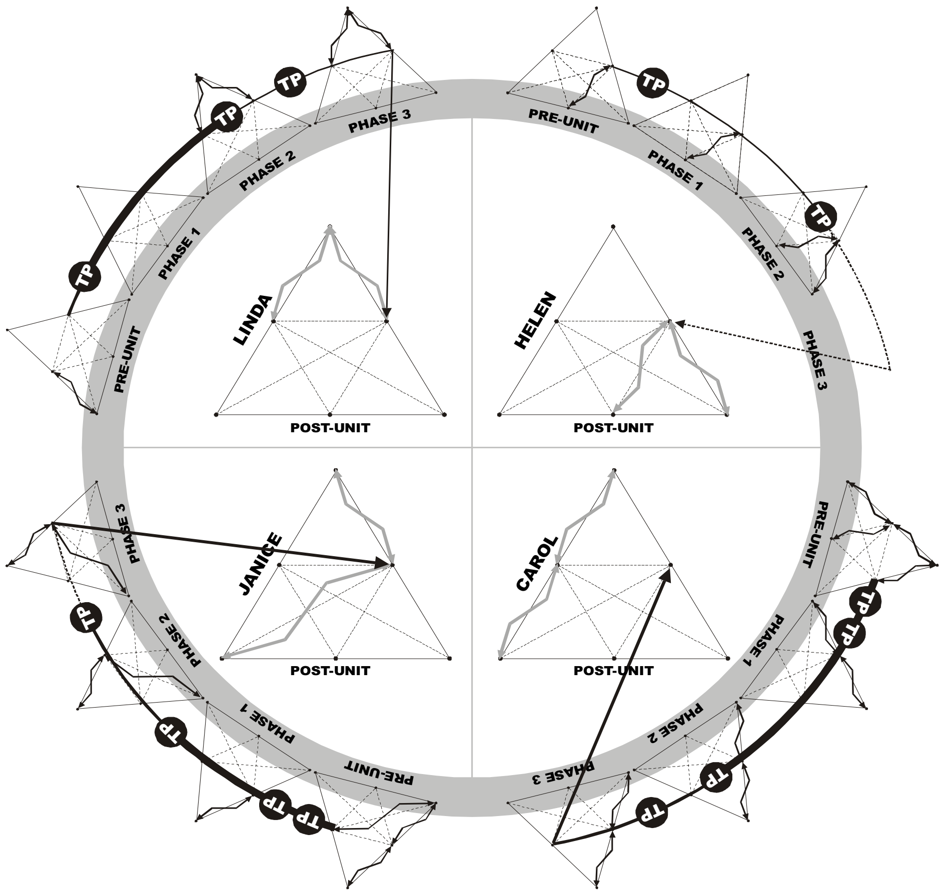

Figure 2. Transformation Model

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Local and Distributed Interaction in a Collaborative Knowledge Building Scenario

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Abstract. The structure and organization of a learning environment has implications for how students organize their collaborative interactions and learning activities. Investigating how students understand and utilize the collaborative conditions in a learning environment is thus a key issue to obtain insight into how to improve the design of such environments. In this paper we identify how collaborative knowledge building is produced in distributed and co-located interactions between students and discuss how this is related to the design of the learning environment.

Keywords: Interaction analysis, distributed collaborative learning, inquiry learning, knowledge building.

INTRODUCTION

In the DoCTA project (Design and Use of Collaborative Telelearning Artefacts) the focus is on the design and use of technological artefacts to support collaborative learning in distributed settings (Wasson, Guribye, & Mørch, 2000; Wasson & Ludvigsen, 2003). One of the most important goals of DoCTA is to develop knowledge about how to create a good learning environment for students with the help of information and communication technologies (ICT). A central aspect of such creation is how students work, both individually and collaboratively in a discipline. As part of DoCTA we have organised a number of different field trials and design experiments where students have been working together in different virtual learning environments. In this paper we will report from our last scenario, *genetikk*, where we investigated how the pedagogical design of an ICT-mediated collaborative learning environment enables students to learn complex concepts and how they can go about discussing these concepts in the broader learning community[1].

In this paper we focus on the structure and organization of a learning environment and how students organize their collaborative interactions and learning activities within this environment. Structure and organization here relate to notions of scripts and semi-structured communication interfaces (Dillenbourg, 2002). We believe that detailed investigations of how students actually collaborate and struggle to enhance their understanding are a key issue in order to obtain insight into how to improve the design of such learning environments.

We take a sociocultural perspective on learning and use Interaction Analysis (Jordan & Henderson, 1995) as our methodological framework. By studying the interaction between collaborating students in detail from an IA perspective, we can uncover how the students make their evolving understanding visible to each other (Stahl, 2002) and how the artifacts that they use are an integral part of this process. Small groups of students have been video recorded while collaborating in front of the computer screen. These recordings, combined with ethnographic methods like participant observation and interviews, give a detailed account of how the groups organised their work (Rysjedal, forthcoming). The paper begins with a description of the *genetikk* scenario, which forms the basis of this study. Then one analysis from Rysjedal (forthcoming) is presented. The paper concludes with a general discussion of the findings and how these are related to design of the scenario.

THE GENETIKK SCENARIO

Design experiments (Brown, 1992) can be seen as intervention in educational practice since the researchers, in collaboration with teachers, try to change the way student's work (Ludvigsen & Mørch, 2003). In our design

[1] There have been many empirical studies carried out on the *genetikk* scenario (e.g., Arnseth, 2004; Arnseth, Ludvigsen, Guribye, & Wasson, 2002; Brændshøy, 2003; Bråten, 2002; Kolstø, 2003; Ludvigsen & Mørch, 2003; Roness, 2003)

experiment we intervened in grade 10 natural science education by introducing an ICT-mediated collaborative learning scenario in gene technology, *genetikk*. In *genetikk* a cross curriculum scenario of natural science, religion & ethics (KRL) and Norwegian was developed collaboratively between the researchers and teachers and the learning goals related to the biological, ethical and societal aspects of gene technology. The pedagogical approach was progressive inquiry learning (Muukkonen, Hakkarainen, & Lakkala, 1999) and a web-based groupware system, FLE3, that supports this model was used as the main learning technology. Students in two classes collaborated in both co-located (within groups in a class) and distributed (between groups in two different Norwegian cities) settings to share and discuss ideas and arguments around scientific and ethical questions related to gene technology. In this section we elaborate on the design rationale behind the scenario by detailing the pedagogical approach and the didactic design and then introduce the technological environment and describe the deployment of the scenario.

Pedagogical Approach and Didactic design

Progressive inquiry learning is an approach to collaborative knowledge building (Scardamalia & Bereiter, 1996) where students engage in an research-like process to gain understanding of a knowledge domain by generating their own problems, proposing tentative hypotheses and searching for deepening knowledge collaboratively. As a starting point for progressive inquiry learning, a context and the goal for a study project needs to be established in order for the students to understand why the topic is worthwhile investigating. Then the instructor or the students present their research problems/questions that define the directions where the inquiry goes. As the inquiry cycle proceeds, more refined questions will emerge. Focusing on the research problems, the students construct their working theories, hypotheses, and interpretations based on their background knowledge and their research. Then the students assess strengths and weaknesses of different explanations and identify contradictions and gaps of knowledge. To refine the explanation, fill in the knowledge gaps and provide deeper explanation, the students have to do research and acquire new information on the related topics, which may result in new working theories. In so doing, the students move step by step toward building up knowledge to answer the initial question. The role of the teachers is to be a facilitator for the students. The teachers can stimulate self-regulation by the students by giving comments and advice, both within the classroom and in the online environment

The didactic design was inspired by the progressive inquiry approach to knowledge building and has elements of a script as defined by Dillenbourg (2002). Animated by a trigger video[2] to set the context and supported by the structure and resources in the learning environment, the students themselves will identify problems on which to work, decide where they wanted to search for information, participate in inquiry learning cycles and create newspaper articles. We developed a set of activities with instructions which included assignments related to the inquiry learning cycle (e.g., generate scientific and ethical questions about gene technology; engage in inquiry about selected questions, compose scientific explanations, etc.) and products related to expressions of what they have learned (scientific and ethical questions, science questions for use on a test, write individual and collaborate texts on opinions about an argument or a discussion about a scientific or ethical question to be published in the national school newspaper).

The digital learning environment

A web portal was designed in order to provide the students with a shared online space. From this portal the students had access to various learning resources, collaboration tools, and a tool for Internet publishing called Skoleavisa (an online newspaper generator available for all schools in Norway). Among the learning resources they could find an online text book (previously written by 2 of the DoCTA researchers), a Norwegian encyclopaedia, animations, a newspaper database called Atekst and some selected links to external resources on the Internet.

The main tool for collaboration was Future Learning Environment 3, FLE3 (http://fle3.uiah.fi). FLE3[3] is designed to support collaborative knowledge building and progressive inquiry learning (Muukkonen et al., 1999). To support the collaborative inquiry learning process, FLE3 provides several modules, such as a WebTop, a Knowledge Building module, and an Administration module. The Web Top provides each group with a place where they can store and share digital material with other groups. An automatically generated message that tells what has happened since the last time they visited FLE3 also appears here. The Knowledge Building module is considered to be the scaffolding module for progressive inquiry and it can be seen as what Dillenbourg (2002)

2 We edited a Norwegian National Broadcasting Corporation (NRK) documentary on gene technology to 4 5-minute segments, each presenting a different theme within genetic technology.

3 FLE3 was developed by the Learning Environments for Progressive Inquiry Research Group at the UIAH Media Lab, University of Art and Design Helsinki in cooperation with the Centre for Research on Networked Learning and Knowledge Building, Department of Psychology, University of Helsinki.

calls a semi-structured communication interface. It is a shared database where the students can publish problem statements or research questions, and engage in knowledge building dialogues around these problems by posting their messages to the common workspace according to predefined categories which structure the dialogue. These categories are defined to reflect the different phases in the progressive inquiry process and included: Question, Our explanation, Scientific explanation, Summary, Comment and Process Comment. We added a digital assistant to FLE3 (Chen & Wasson, 2003) to support both the students and teachers in monitoring what happened inside FLE3 (Dragsnes, Chen, & Baggetun, 2002). All messages are visible as lists of messages which can be sorted by topic (thread), person, category and date. In addition to FLE3, a combined chat and mind mapping tool (Dragsnes, 2003) was developed and made available for the students to add support for synchronous communication.

Deployment

Genetikk took place over 31 hours during the three last weeks of September 2002, and involved two grade 10 classes, one from Bergen (24 students) and one from Oslo (27 students). Five of the 31 hours were concurrent (i.e., both classes worked on genetikk at the same time) and synchronous communication was possible. The scenario began with each class viewing the trigger video on genetic technology. Then the students brainstormed about questions related to genetic technology. This brainstorming session generated a long list of questions from the two classes, and the teachers used these questions in order to make one single list of questions with 12 scientific questions and 12 ethical questions about genetics. This list of questions was published on the web portal.

The two classes were then divided into *local groups* with 3 or 4 members, and each of the local groups in Bergen was connected to a local group in Oslo to form a *composed group*. The scenario had two phases, and in the first phase the composed groups discussed the list of questions and decided on three scientific questions to work on. These questions were posted as problem-statements in FLE3 before they started to search for and discuss information around their questions. Whenever they found something relevant, they could post it as a note in the Knowledge Building module in FLE3. After having explored the questions for about a week the students should use the information they had gathered in order to write at least three different articles about genetics. These articles were published in Skoleavisa, the online newspaper generator.

In the second phase of the scenario the focus was turned to the ethical aspects of gene technology. The list of questions was revisited, and this time the composed groups should decide on 3 ethical questions on which they wanted to work. The same inquiry process was repeated in this phase, with about one week of inquiry of questions before publishing articles in Skoleavisa. It was believed that focusing on scientific aspects before they turned to the ethical aspects would increase the students' abilities to argue on their ethical viewpoints. By the end of the project 60 articles were published in the online newspaper and every group had contributed with articles. Some of the groups, however, produced more articles than others. One of the composed groups had published 13 articles, while another group had published 7 articles.

Research procedure

The authors participated in the didactic design, the design of the digital learning environment and in observations and data collection during the scenario deployment. In both schools, the field activities were observed[4] by at least 1 researcher and one person from the technical staff. In this paper we use empirical data collected from following a distributed group we refer to as Composed A. Composed A comprises one local group from Bergen (Bergen A) and one local group from Oslo (Oslo A). Bergen A and Oslo A were video recorded while they were working on *genetikk*. These recordings, synchronized with logs of their computer activity and a screencam of their interactions in the environment, give a rather detailed representation of how Bergen A and Oslo A were working and interacting. A content log of all the recordings gives an overview of how the group organised their work, and episodes that were considered particularly interesting have been transcribed according to transcription conventions described in Silvermann (1997) and translated from Norwegian to English. Furthermore, all their postings in FLE3 are stored on CD-rom and as printouts and group interviews were also carried out after the project period (see Roness, 2003). Articles and inquiries within other groups have only been briefly analysed in order to make sure that the work within Composed A is not noticeable different from the work within other groups.

[4] The authors of this paper observed the students in Bergen and had daily contact with researchers observing the students in Oslo.

DISTRIBUTED AND LOCAL KNOWLEDGE BUILDING

Investigation of the notes in the Knowledge Building Module of FLE3 revealed that apart from the negotiations of which questions to select for inquiry, there had been minimal interaction between the local groups. Composed A collaboratively selected three Scientific and three Ethical questions on which they wanted to work (they were to work on each set of questions for one week). For each of the six questions the students created a separate thread in the Knowledge Building module where they were supposed to engage in collaborative inquiry of the questions. They were to post their own explanations, post scientific explanations they found in different resources, comment on each other entries, follow up with new questions, etc. As table 1 shows, there were only two threads with more than four notes. Thus, the students did not use the Knowledge Building module and the categories as intended in order to support the progressive inquiry model. For more detailed analyses about the students' use of the categories in FLE3, see Ludvigsen & Mørch (2003) and Arnseth (2004).

Table 1: Number of notes posted within each category in the Knowledge Building module of FLE3

	Scientific phase			**Ethical phase**		
Category Thread	**SQ 1**	**SQ 2**	**SQ 3**	**EQ 4**	**EQ 5**	**EQ 6**
Question	2	3	2	1	1	1
Our explanation		1	1	3	3	3
Scientific explanation	1	2				
Comment						
Process-comment	1	1	3			
Summary		2	3			
Total	4	9	9	4	4	4

Careful examination of the newspaper articles, however, indicated that despite the limited use of the Knowledge Building module the questions had been thoroughly investigated by the students (Rysjedal, forthcoming). Examinations of how the students actually collaborated to solve their tasks revealed that it was primarily within the face-to-face interactions going on in front of the computer screen that we could find evidence of students struggling to enhance their conceptual understanding.

The extract below is from an episode where the two girls, Gro and Liv, are investigating the question "Can all kinds of food be genetically modified?". They have decided that in order to be able to answer this question they first have to find out what gene modification means. Gro is searching for information about this on the Internet while Liv is reading in an encyclopaedia lying in her lap. Liv finds information in the encyclopaedia that she thinks explains gene modification, and tries to get Gro's attention by asking if she understands gene modification.

Extract 1

1. Liv: Yes, I think I understand it.
2. (8.0)
3. Liv: Do you understand it?
4. Gro: What then?
5. Liv: This.
6. Gro: Yes.
7. Liv: What gene modification is?
8. Gro: Yes- No.
9. Liv: What is it then?
10. Gro: Well it is- No.
11. Liv: Try then.
12. (1.5)
13. Gro: What gene modification is? Well it is (.) to replace, isn't it. (2.5) No I don't understand it at all.
14. Liv: It is modification of an organism's genetic composition by the use of gene and cell technology. ((Liv is
15. reading from an encyclopedia))
16. Gro: So, what are they doing, then?
17. Liv: Then they are changing the genetic material.
18. Gro: So that (.) No, I don't understand it.
19. ((Liv is reading silently in the encyclopaedia.))
20. (7.0)
21. Liv: Well, that's what they are doing. (1.5). Well, but that has- How- But what- What connection can that have
22. with food. (1.0) Then it has to be meat.
23. Gro: It has to be meat, doesn't it?

24. Liv: Well, but when you talked about rice.
25. (2.0)
26. Gro: Ehh. Then we just have to read that rice thing properly.

This extract demonstrates how Liv encourages Gro to try to explain her understanding of what gene modification means (see lines 1-11). Gro seems to have some ideas about what this means, but she has trouble articulating them and concludes that she does not understand it at all (line 13). Liv reads the explanation from the encyclopaedia, but Gro maintains that she still does not understand it. The reason is that the explanation Liv read did not explain what they are doing (see line 16). She thereby argues that in order to get a better understanding of what gene modification is, they have to find out what is actually done when organisms are gene modified. In other words, she points out a direction for their further work.

Liv turns to the encyclopaedia again. After having looked in the encyclopaedia for seven seconds she questions how the explanation given there can be related to food. She further argues that if this is related to food it has to be bound to meat. Gro agrees to this argument. They thereby reveal that according to their understanding it is only animals that can be gene modified. But Liv is also critical to this assumption as she points out that they have previously come across an article about gene modified rice. Gro's answer to this critique is that they have to explore the rice article more thoroughly. In this way they identify yet another area they have to explore.

When Liv encouraged Gro to formulate her own explanation before she introduced the explanation from the encyclopaedia, she arranged for an opportunity where they could compare the two explanations and identify gaps or contradictions. They did not explicitly compare the two explanations, but they did evaluate the explanation from the encyclopaedia by pointing out that it did not explain what they are actually doing. Thus, they identify a weakness in the explanation and an area they have to explore further to provide a deeper explanation. Furthermore, they related this explanation to their initial question and concluded that according to their understanding of the explanation it had to be related to meat. But they also critically evaluate this assumption by pointing out that they have previously come across information about genetically modified rice.

The students also generated more specific questions during their investigations of their initial questions. These questions were usually related to information that was found or theories that were generated during their working process. The extract below is from an episode where Gro and Liv are editing a note on their Webtop. As they are working on this note, Gro introduces a new question about gene modified food.

Extract 2

1. Gro: Gene modified food. Is that for example like tomatoes that are huge?
2. Liv: Yes, it does not ripen that quickly. (1.0) It keeps longer.
3. (3.0)
4. Liv: Do tomatoes have genes then? ((They look at each other and smile))
5. Liv: I have not heard anything about that. Well.
6. ((Gro starts to read the text in the note again))

In line 1 Gro is asking if gene modified food can be tomatoes that are huge. Thus, she is trying to relate gene modified food to something familiar – tomatoes that are huge. Liv confirms that gene modified food can be tomatoes that are huge, but she also introduce another characteristic – that it does not ripen that quickly. That she mentioned this specific characteristic can be related to the fact that they the previous day found an article on the Internet about tomatoes that have had an extra gene inserted in order to prevent production of the enzyme that makes tomatoes ripen. However, in line 4 it is being questioned whether tomatoes really have genes. But this question is not explored any further. They just look at each other and smile, and Liv proclaims that this is not something she has heard about (line 5). After that they continue to edit the text in the note.

Even though many of the questions that were generated during their investigations were interesting and important questions they had a tendency not to be explored any further. The only question (apart from the initial questions) that they returned to several times was the question about what it really means to genetically modify food. The rest of the questions just seemed to disappear as they moved their attention to a new activity, such as editing a Note in FLE3, or reading something on the screen. Nevertheless, one can assume that the questions affected what information they considered relevant in their exploration of the numerous information sources they had available.

DISCUSSION AND CONCLUSION

In this study it was found that most of the interaction within the composed group was concerned with which questions they should choose for inquiry. When the students started to investigate the questions the interaction within the composed group was greatly reduced. Both local groups complained about lack of feedback from the other group, and whenever the students found relevant information they saved the information on their local group's Webtop instead of posting it in the Knowledge Building module. The focus seemed to turn from a collaborative inquiry of the questions towards local production of articles that they could publish in the online newspaper. The moderate interaction between the distributed groups can partly be related to the didactical design of the scenario. Although the teachers encouraged the students to engage in inquiry learning by using the Knowledge Building module, it was primarily the articles in the newspaper that the students were made accountable for at the end of the project (Arnseth, 2004). This may suggest that assessment methods that emphasise process as well as product need to be used and perhaps it would have been better that they not know about the articles they would produce right from the beginning, but instead introduce them after the inquiry cycle.

Despite the moderate use of the Knowledge Building module in FLE3, however, the students were engaged in detailed investigations of the questions. In many ways the face-to-face interactions in front of the computer screen resembled certain aspects of inquiry learning – they tried to articulate their own explanations, they assessed strengths and weaknesses in the explanations, and they searched for information in order to provide further explanations. The talk in front of the screen was identified as the most important part of the collaborative knowledge building that took place during the scenario, but it was also found that many important questions and ideas that emerged in face-to-face interactions were never explored further. Their reasoning and deepening explanations became *temporal* and *local,* not *persistent* and *shared* in the Knowledge Building module, thus the other local group could not take part in the knowledge building and both groups missed out on the opportunity to use each others insights and knowledge in furthering their understandings of gene technology.

While the Knowledge Building module was envisaged to support the students' knowledge building in this scenario, it was primarily in the face-to-face interactions in front of the screen that we could find evidence of any kind of knowledge building. Exploring how such local knowledge building can be made more persistent and shared is seen as an interesting possibility for improvement of the learning environment. An obvious solution would be to let each student work with a separate computer, and thereby forcing them to communicate through the digital learning environment. This would probably have increased the interaction within the composed group and might have resulted in a more distributed collaborative process. It would, however, also remove the fruitful discussions between the co-located participants. Thus, it remains an open question as to whether such a solution would be advantageous for the overall learning activity.

One should never underestimate the role that the institutional dimension plays in such design experiments. Institutional aspects influenced both the design and the students' activity. In the design phase we were constrained by the availability of computers in the school in Bergen and thus had to plan for local groups that would share a computer. The design was also constrained by the curriculum where gene technology was a natural science unit of approximately 15 hours. We were, however, able to extend these hours by creating a cross discipline unit that included their religion & ethics and Norwegian hours during these 3 weeks. The result was that both science and ethical aspects were in focus during the inquiry, and there was an emphasis on writing skills in the final product. The challenges for the students were many. They were dealing with both a new subject matter (gene technology) and with a new way of working (inquiry learning) and they had to appropriate a new technology (FLE3) within a limited time frame and learn how to work with another class in another school. There is also some evidence in the empirical data (Rysjedal, forthcoming) that the students were having trouble with the "asynchoronous" nature of the inquiry process. They would post a note and then sit and wait for a response from the matched local group, but the other class might not be logged on until the next day (remember there were only 5 hours where the classes worked on *genetikk* simultaneously). This expectation of immediate response and feedback is ingrained in much traditional classroom behavior, referred to as an initiation-response-feedback (IRF) pedagogical exchange (Sinclair & Coulthard, 1975) and when they did not receive immediate response and feedback, this caused frustration. We did, however, see evidence in the local group of the Initiation-**Discussion**-Response-Feedback (IDRF) pedagogical exchange Mercer & Wegerif report on in their studies of children's talk in front of computers (Mercer & Wegerif, 1999; Wegerif, 1996).

Understanding what is going on in ICT supported scenarios is a complex process and a lot of empirical data needs to be examined in order to make sense of what is going on. In this paper we have given insight into how we try to understand how the structure and organisation in *genetikk* has influenced the way the students have worked. We cannot only look at their interactions within the local and composed group in light of the design of *genetikk*, but must always remember that it is situated in an institutional setting that not only imposes constraints on scenario design, but has also influenced student expectations and ways of working over a number of years. How all these factors can be understood, and how they influence design is a challenge to the CSCL community.

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Supporting Collaborative Discovery Learning by Presenting a Tool

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Abstract. In collaborative discovery learning students jointly perform experiments to test generated hypotheses with as a result the co-construction of knowledge by means of sharing knowledge and negotiating. In this study, we introduce the Collaborative Hypothesis Tool (CHT), which guided 15 of 25 dyads through the collaborative discovery learning process. The results show that working with the CHT can influence the use of communicative and discovery activities, which can lead to a better learning performance. Future research should be aimed at the stimulation of the use of the tool, since the learners did not use the tool very frequently.

Keywords: Cognitive tools, Collaborative discovery learning, Communication, Discourse analysis,

INTRODUCTION

Collaborative discovery learning combines two constructivist approaches to learning: collaborative learning and discovery learning. In collaborative discovery learning, learners communicate and work together in order to jointly construct knowledge by means of sharing knowledge and negotiating. In discovery learning, by altering the variables and parameters in a simulation and observing the effects, learners can attempt to uncover the rules governing the simulation, and in so doing, build knowledge (De Jong, & Van Joolingen, 1998; Njoo, & De Jong, 1993; Njoo, 1994). The skills and processes employed by learners in discovery learning environments are similar to the skills employed in scientific discovery (Klahr, & Dunbar, 1988; Van Joolingen, & De Jong, 1997). A common distinction in scientific discovery processes is between *regulative* discovery processes, like planning or monitoring, and *transformative* discovery processes, which represent the generation of new knowledge (De Jong, & Njoo, 1992; Njoo, & De Jong, 1993). Scientists' interactions are important in the scientific thinking and reasoning process, because many new ideas arise through externalization of thoughts (Dunbar, 2000). As discovery processes are similar to the scientific processes that scientists use, it can be assumed that successful discovery learning processes can be positively influenced by learning collaboratively (Salomon, & Globerson, 1989). Support for the idea that collaborative discovery learning can be fruitful for the learning process comes from a study carried out by Okada and Simon (1997), where dyads of learners working together were more effective in discovering rules, because they used more explanatory activities compared to learners working individually. In a previous study (Saab, Van Joolingen and Van Hout-Wolters, in press), it was found that communicative activities can contribute to essential stages in a collaborative discovery process. For example, directive and informative activities can contribute to the testing of hypotheses, while argumentation can lead to a successful process of conclusion. This leads to the conjecture that when learners are encouraged to use these communicative activities, a more successful discovery process can be the result.

In the current study, we are interested in supporting the learning processes in collaborative discovery environments. Discovery processes need support (e.g. De Jong & Van Joolingen, 1998), and although in collaborative settings learners can support each other, collaborative discovery learning also needs support. Several studies endorse the view that collaboration without instruction or support on how to collaborate does not automatically lead to a successful learning process or product (Mercer, 1996; Webb & Farivar, 1994). This support can be given as an *instruction*, like the RIDE instruction in a study of Saab, Van Joolingen and Van Hout-Wolters (submitted), or it can be built into the learning environment as *cognitive tools* (Lajoie, 1993; Van Joolingen, 1999).

Cognitive tools are computer technologies that help learners to carry out cognitive tasks. Learners do not learn *from* technologies, but they learn when *working with* technologies, with the technology as a support to the cognitive actions of the learners (Salomon, 1993). According to Lajoie (1993), cognitive tools can serve several functions in assisting learners.

Collaboration can improve learning as shown by several studies (e.g. Van der Linden, Erkens, Schmidt, & Renshaw, 2000; Springer, Stanne, & Donovan, 1999). When working collaboratively, learners externalize their thoughts and become aware of their own ideas and those of their collaborator. By formulating their ideas, possible defects in cognitive of metacognitive processes can become perceptible (Van Boxtel, 2000;

Van der Linden *et al.*, 2000). By internalizing these verbalized thoughts and ideas in an elaborative way (Roelofs, Van der Linden, & Erkens, 1999), by giving elaborative explanations (Webb, 1994) and asking questions (King, 1997), the learning process will succeed more effectively.

Examples of cognitive tools to support discovery learning can be found in the learning environment BioWorld (Lajoie, Lavigne, Guerrera, & Munsie, 2001). BioWorld helps learners with the externalization and evaluation of their reasoning by presenting them with an evidence palette, where evidence is posted in support of the hypothesis generated by the learners, and a belief meter, where the learners can show how comfortable they are with the diagnosis (or hypothesis) stated. The evidence palette is based on the tool that Van Joolingen and De Jong (1991; Van Joolingen, 1993) developed, called the hypothesis scratchpad. The hypothesis scratchpad supports the process of generating hypotheses by presenting elements with which to build hypotheses, like variables and relations.

In our study, we introduce a cognitive tool that can also support collaborative processes between learners. The template offered by the tool should serve as a trigger for collaborative discovery processes. Our cognitive tool, the Collaborative Hypothesis Tool (CHT), is based on the hypothesis scratchpad of Van Joolingen and De Jong (1991; Van Joolingen, 1993). This CHT guides the learners through the processes of collaborative discovery. Moreover, the learners are encouraged to work in a collaborative manner by stimulating them to argue about what hypotheses they should generate and test. In addition, the learners are instructed on how they should test their hypotheses by effectively varying certain variables, and to stimulate them to check if the hypotheses generated are the same as the answer found after doing experiments. We expect that the learners who work with this tool will show more communicative activities that contribute to successful collaboration, and more effective discovery activities, which will lead to better learning results, compared to students who do not use the tool. Our research questions are:

How do the learners use the Collaborative Hypothesis Tool in a collaborative discovery environment?

Does the cognitive tool influence the communicative activities and discovery activities in such a way that the collaborative learning process and the discovery learning process and product improve?

METHOD

Subjects and design

Research participants were 32 dyads of tenth-grade students (15-16 years old) of six secondary schools in Amsterdam who were enrolled in pre-university education with physics as a subject in their examination. The mean age was 15.6 years. The design of the study was a pretest-posttest-control-group-design. The students were randomly divided in an experimental group and a control group. Because of technical reasons (i.e. chat not completely logged or problems with the connection between the two computers) and one chat log with utterances in a language other than Dutch, we had to exclude seven dyads from the data analysis, which resulted in an experimental group containing 15 dyads and a control group containing 10 dyads of students.

Learning environment and task

All students worked together with a learning environment that was based on a computer simulation, "*Collisions*", developed in SIMQUEST (Van Joolingen & De Jong 2003; Saab, et al., in press) [1]. Dyads of students worked collaboratively on two computers with a shared interface, communicating through a chat channel. Students were not familiar with the level "*Collisions*", but were acquainted with the variables presented in the environment.

Before working with the application *Collisions,* by working with a similar environment, also created in SIMQUEST, all learners became familiarized with the learning environment. Additional instructions on collaboration (the RIDE rules (Saab, Van Joolingen, Van Hout-Wolters, submitted)) were also provided. RIDE is based on four general rules, namely Respect, Intelligent collaboration, Deciding together, and Encouraging. The aim of providing this instruction is to have the students communicating more effectively in order to improve the collaborative performance in the learning environment. An earlier study (Saab et al., submitted) showed that instructing these rules can lead to more effective communication.

The learning environment *Collisions*, with which the learners worked after they had received the instruction and practiced with the rules, was different for the experimental group and the control group. The experimental group worked with the same application as the control group, but in addition was presented with

[1] "Collisions" was developed by Hans Kingma and Koen Veermans (Universiteit Twente). SimQuest was developed in the SERVIVE project coordinated by the Universiteit Twente.

a CHT intended to support learners in the generation of hypotheses, planning and concluding. The first process of discovery learning orientation was paid attention to in the assignments, were learners were stimulated to explore the simulation together. This tool consisted of a hypothesis scratchpad, based on a similar tool described in Van Joolingen (1993). In order to use the tool in a collaborative environment, several adaptations were made to it.

Measuring learning outcomes

In this experiment, we identified two types of learning outcome. One is associated with the performance *within* the learning environment; the other is a measure of what is learned *from* this performance. For the latter, the results of a domain knowledge posttest and the gain in score related to the domain knowledge pretest is used as a measure. For the performance within the learning environment, the students could get three points for each assignment. All together, the learners could gain 105 points, divided over 35 assignments (17 open-question assignments and 18 multiple-choice assignments). The multiple-choice assignments were worth 3 points. When the learners gave an argumentation in addition to the plain answer on the open-question assignments, they gained one or two points, depending on the completeness of the answer given. The amount of points gained by a team is taken as a measure of learning results within the learning environment. We label it as SWLE (score within learning environment). The pretest-posttest measure is taken individually, while SWLE is measured on dyads. The domain knowledge pretest and posttest each consisted of two domain knowledge tests, an Explicit Knowledge Test, which tests the learners for declarative knowledge, such as facts and formulas, and a WHAT-IF Test (Swaak, 1998; Veermans, De Jong, & Van Joolingen, 2000). Both tests were developed specifically for the domain of *Collisions*[2] and were administered on-screen. Unfortunately, the reliability of these tests were very low and we did not conduct further analyses.

Procedure

For making up dyads, we chose a heterogeneous group composition (Saab et al, submitted), since research has shown that groups composed of students with differing levels of school grades are more successful working together than are groups made up of students with similar learning results (Blatchford, Kutnick, Baines & Galton, 2003). Participants in the study attended two sessions. In the first session, the participants received individual instruction on collaboration (the RIDE rules). After the instruction, the students practiced collaboratively with an application with logical thinking problems. In this way, the students could practice applying the rules that they had learned earlier in the session. The second session started with the pretest on domain knowledge for all students. Then, they worked together for 90 minutes with the application *Collisions* in the learning environment SIMQUEST, and it ended with the domain knowledge post-tests. The experimental and control groups worked with different versions of the learning environment, as explained in section 'learning environment and task'.

Data collection

All communicative and discovery learning activities were logged and were put together in a single protocol for each dyad. A three-dimensional analysis scheme was used to analyze the protocols. The scheme has been developed and used in previous studies (Saab, et al., in press). The dimensions are: a) communicative activities, b) discovery transformative learning activities, which promote the generation of information (Njoo & De Jong, 1993), and c) discovery regulative learning activities, which support and guide the learning process (Njoo & De Jong, 1993).

In the protocols, each chat utterance, defined as a verbalization typed in a chat window, was scored on the dimensions communicative activities, discovery transformative activities, and discovery regulative activities. Chat utterances were coded on all three dimensions. The SIMQUEST action simulation running was coded only as a discovery transformative activity, collecting data. Two independent raters rated 10% of the protocols, after both raters were trained in using the analysis scheme. Cohen's kappa of inter-rater reliability between the two raters was .94 for the communicative dimension, .89 for the transformative discovery dimension, and .95 for the regulative discovery dimension, which can be considered as good agreement (Fleiss, 1981).

Besides the analyses of the protocols, the use of the Collaborative Hypothesis Tool was investigated for the experimental group. The use of the CHT is measured by the following variables: a) The number of hypotheses generated within the tool with each question where the CHT was presented to the learners, b) The

[2] Both tests were developed by Janine Swaak.

total number of hypotheses generated while using the CHT, c) The proportion of planning activities while using the CHT, d) The proportion of checking if the answer is the same as one of the hypotheses generated while working with the CHT, and e) The proportion correctly answered questions after using the CHT. The frequency of planning and checking if the answer is the same as one of the hypotheses generated while working with the CHT is logged in the answers on the assignments and is, as a consequence, something different than a communicative or discovery activity logged in the protocols.

RESULTS

First, we analyzed the use of the CHT, then we present the differences in learning results between the experimental and the control group, and finally we present the analysis of the learning process.

Collaborative Hypothesis Tool

Relations between the measures of CHT use and activities, including a measure of asymmetry in communication, were tested using Spearman correlation analysis. Asymmetry in communication is the difference in the number of utterances between the participants in one team, presented as a percentage of all utterances of one team. Significant positive correlations were found between the total number of hypotheses generated in CHT and communicative activities all together (r=.58; p<.05). Significant correlations between planning in the CHT and Deciding together activities (r=.53; p<.05), and regulative activities overall (r=.54; p<.05) are found. Significant positive correlations were found between the proportion correctly answered questions after using CHT and Deciding together activities (r=.68; p<.01), transformative activities overall (r=.58; p<.05), and regulative activities overall (r=.61; p<.05).

Learning results

We did not find any significant differences between groups for the performance within the learning environment.

Relation between activities and SWLE for the experimental and control group

To detect which communicative and discovery activities have a positive significant relation with SWLE, we conducted a Spearman correlation analysis between those variables for the experimental and the control groups. We also computed the Fisher's Z' scores to compare the correlation of the experimental and control groups. There are several significant positive correlations in the experimental group: deciding together activities (r=.62; p<.05), transformative activities overall (r=.55; p<.05), and regulative activities overall (r.53; p<.05) correlate significantly with SWLE. No significant correlations are found between SWLE and the frequencies of activities used in the control group. We found significant differences in correlation between the experimental and the control groups, with significantly greater correlation coefficients for the experimental group for deciding together activities (p<.05) and regulative activities overall (p<.05).

Learning process

No significant differences were found in use of frequency of communicative activities or discovery activities between the control and the experimental group.

CONCLUSION AND DISCUSSION

To answer the first research question, we investigated how the collaborating learners used the Collaborative Hypothesis Tool (CHT) and what activities they performed. The learners were free in choosing to use the tool, which, unfortunately, resulted in infrequent use of the tool. This indicates that the learners see no obvious advantage of the collaborative tool. Nevertheless, to see whether the tool contributed to learning in the cases it was used, we conducted correlational analyses. We found that a higher level of communication was related to the number of hypotheses stated on the scratchpad. The planning tool (indicating whether and how a hypothesis should be tested) correlated to communicative activities associated with *Deciding together* as well as with regulation. This indicates that the purpose of the planning indicator served its goal, as it seems to stimulate collaborative decision making and learners' regulation processes. For the assignments for which learners used the CHT, *Deciding together* and regulation were positively correlated with the performance on these assignments. A hypothesis that can be formulated, based on these findings, is that the CHT did induce effective communicative processes for those learners that used it, and that this yielded better performance on the assignments. This is supported by the fact that learners in the control group did not show similar correlations between performance and communicative and learning processes. These differences in correlations are significant (Fisher's Z), which means that using the tool could have effects on the learning results.

We did not find differences in score within the learning environment (SWLE) between the experimental and the control groups, but we did find differences in relations between activities and SWLE for both groups. The activities that have a positive significant relation with SWLE in the experimental group –and notably not in the control group-, are confirmation/acceptance, asking for action (which are both connected to the Deciding together rule which is one of the RIDE rules), and regulative activities overall. The same activities have a significant relation with the amount of correctly answered questions after working with the CHT. This may indicate that these activities, especially communicative activities connected to the Deciding together rule, were used more effectively by the experimental group and, moreover, were effective for using the CHT combined with correctly answered assignments.

The hypothesis that the use of the CHT would have an influence on the use of communicative activities or discovery activities was not confirmed. No significant differences in the use of communicative activities were found between the group that used the CHT and the control group. Communicative activities that were mostly used in both groups were informative, elicitative and confimation/acceptance activities, which is in concordance with Saab et al. (submitted). The experimental group showed a high frequency of use of the same communicative activities. The experimental group is similar to the control group in the present study, because both groups received the RIDE rules instructions under the same conditions.

A likely explanation of the lack of differences between the experimental group and the control group is the little use that was made of the CHT in the experimental group. As noted above, the learners themselves did not see obvious benefit in using the CHT. One cause may be that use of the CHT costs time and resources. Also in a study by Lazonder, Wilhelm, and Ootes (2003) where learners could choose to work with the presented tool or not, most of the time they did not. Apparently, learners are inclined to use a tool only when they see direct benefit or when there is pressure to use it. A possible cause of lack of motivation can be the cognitive overload caused by the many windows that popped up when the CHT was activated. The pop-ups that were presented to the control group (RIDE rules pop-ups) where in consistence with the training both groups received. The CHT was totally new for the experimental group; they did not receive training in how to use the CHT. An idea for future research is to give the learners an opportunity to practice with the tool beforehand so that they will know why they should use it, and how they can use it effectively.

In summary, we found little differences on measures of process and product between the experimental and control groups. However, within the experimental group we did find relations between working with the CHT and process and product of learning. It can be concluded that working with the Collaborative Hypothesis Tool can influence the communicative activities in a way that the collective learning results may improve. Furthermore, the CHT can influence both communicative and transformative discovery activities, with the result that working with the tool leads to more performance of simulations, and performance of simulations is related with giving good answers after working with the tool. Regulative activities seem to be necessary while working collaboratively with the tool with the aim of generating correct answers or it is possible that the tool may evoke the use of regulative activities. In future research, when presenting the CHT to learners, they should be informed about the benefits of the CHT and be trained in the use of the tool before using it in experiments. Discovery learning needs support and so does collaborative learning. Learners who work in a collaborative discovery learning environment should now why and how to work with all features of the environment properly, in order to use the presented tools effectively.

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Experiences with Interactive Lectures –

Considerations from the Perspective of Educational Psychology and Computer Science

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Abstract. The conventional lecture scenario implicates fundamental didactic problems due to a lack of interactivity and opportunity for feedback. In an interactive lecture, each student is equipped with a lightweight, mobile device that can be used to wirelessly interact with the lecturer during the lesson. This creates an additional channel of communication. In this paper, we present our experiences with this new scenario over the last three years. After discussing the benefits of interactive lectures, similar projects, and possible mobile devices, we introduce the software-toolkit used in our scenario and present a selection of results from over our six major studies.

Keywords: interactive lectures, ubiquitous computing, wireless communication, blended learning

INTRODUCTION

In Germany, governmental and scientific institutions (e.g. Bundesministerium für Bildung und Forschung, 2001; Fraunhofer-Gesellschaft, 2002) have launched several programmes to introduce the use of new media into the system of higher education. These aim to improve the quality and effectiveness of teaching in universities through the use of multimedia elements. Appropriate new teaching media and learning procedures should help to achieve a better adjustment to the individual learning needs, learning rates, and time budgets of students, as well as afford the instructors more flexibility in their teaching.

But despite the various multimedia projects and the efforts on the part of dedicated instructors, the introduction of educational media has led to an only partial modernisation of the universities. This is particularly evident in the classical university teaching-learning scenario: the lecture. Lectures in universities have profited from many technical advances over the last few years. Blackboards were replaced by overhead projectors, which, in turn were substituted by video projectors and electronic whiteboards (Geyer & Effelsberg, 1998). Most lecture halls nowadays are equipped with computers, as well as video and audio systems, thus allowing the integration of every possible type of media into the lecture.

Nonetheless, the basic teaching paradigm continues to remain largely unchanged; one of the few exceptions is the scenario of the telelecture (e.g. Datta & Ottmann, 2001) or digitally recorded lectures (Zupancic & Horz, 2002). The main disadvantage of lectures is their lack of interactivity: Conventional lectures can be characterized as situations in which a teacher presents new information to the learners without guiding their learning processes. The limited opportunities for interaction in lectures engender a set of problems regarding students' attention and motivation, as well as the adaptivity of the lecturer's instruction.

Lecturers often attempt to overcome such problems by asking questions, to trigger feedback on how well the students have understood the presented material, as well as to provoke their active participation in the meetings. This is problematic in lectures with a large audience, since only a few students are able to interact with the lecturer in this way. The overwhelming majority will not benefit from this form of interactivity. Further problems arise if the lecturer wants to get feedback on how the students accept the lecture or their suggestions for improvements. In lectures with a small audience, the teacher can typically deduce this information from the students' reactions, e.g. bored expressions. In meetings with large audiences, however, this information is usually gathered by passing out feedback questionnaires to the students at the end of the lecture period. Unfortunately, this approach is rather imprecise and does not allow any assessment of individual lecture elements. Nor can the lecturer react quickly to problems. Other forms of interactivity are spontaneous questions by the students. These can often be difficult in large lectures. First of all, due to time constraints, not all students are able to ask questions. Secondly, many do not dare to ask questions in front of a large audience. Finally, if students can pose questions only at certain times, these will be out of context when finally put. Given all these problems, most students do not interact at all during the lecture.

Thus, despite the possible use of different media to illustrate lecture topics, interaction is hardly possible in mass meetings. This unidirectional communication leads to several motivational and cognitive problems:

From a pedagogic-psychological view, learning (in lectures) has to be reconstructed as an active process (e.g. Ernest, 1995; Jonassen, 1994; Honebein, 1996; Wilson & Cole, 1991). Interactivity represents an opportunity for the learner to take a hand in shaping the informational, communicational and learning processes, rather than remaining a passive recipient; thus, the active involvement of the learners has a great impact upon successful learning (Ramsden, 1992). In respect of the learning success in lectures, empirical results state that while lectures are not generally ineffective, they still are not suitable for a global knowledge transfer (see for an overview Gage & Berliner, 1996; Peterson, 1979).

Directly connected to the problem of the low interactivity in this method of teaching is the lack of adaptivity of the teacher's behaviour: During the lecture, the instructor can only adapt a limited portion of the contents or topics of his lecture to the learners' state of knowledge. On the other hand, in the instructional-psychological context, adaptivity is an essential tool to improve the learning process. The underlying rationale is to adapt explanations or curricula to the learners' current state of knowledge, thereby achieving greater efficiency and efficacy of instruction. Empirical findings reveal the effects of diverse learning-centred measures upon learning success (Sass, 1989; Cronbach & Snow, 1977; Bligh, 1971).

Finally, an essential problem in lectures is the continuous attention required of the learner, usually over 90 minutes. This requirement is not realistic: Usually, the attention span is only about 20 minutes (Smith, 2001). Subsequently, an activity change must follow if students are to maintain their attention (e.g. a change from the lecture to the discussion phase). Studies show that a decreasing mental performance is responsible for the inferior knowledge acquisition (e.g. Siegel, Siegel, Capretta, Jones & Berkovitz, 1963; Bloom, 1953). However, such activity changes are not foreseen in the classic scenario, and if so, they depend exclusively on the ability of the lecturer (Ramsden, 1992).

In dominant instruction models (e.g. Glaser, 1976; Rosenshine, 1979), the diagnosis of the learners' knowledge status by the teacher is a central element of the educational process: Each instruction cycle contains two diagnostic elements: the diagnosis of relevant learners' characteristics and the diagnosis of the learning achievement, for the planning of the further educational procedure and/or the examination of success in learning. Thus, learner feedback enables an adaptive teaching behaviour, which can lead to an improved learning process. Lecturers, for example, can adapt explanations or contents to the learners' knowledge status, in order to heighten the efficiency and effectiveness of their instruction.

Directed interactivity can strengthen learner-centred instruction. This is further strengthened if the learners feel they can communicate with the lecturer and give him feedback, thus have a real opportunity to affect the learning process - despite the rather passive role as receptive learners. Since successful learning represents an active process, active involvement of the learners should have a large effect on learning.

Effectively increased interactivity should promote students' attention and motivation and, finally, support their acquisition of knowledge. The pre-condition is that lecturers receive more exact information, to enable a micro adaptation of their presentation.

Hence, there are evident theoretical and practical reasons to improve this type of learning scenario or to create a new (more interactive) scenario as a replacement.

An innovative approach to improve interactivity and to realize bi-directional, synchronous communication in lectures is to equip the students with small electronic devices, such as handheld computers. These devices communicate with the lecturer's computer, thus allowing the exchange of information with the lecturer at any time, without disturbing the lecture.

The type of information exchanged can be arbitrarily complex, ranging from a simple "virtual hand-raising" over detailed feedback to quizzes that may even be counted towards the grades of the students. To avoid cost-intensive modifications of the lecture hall, the handheld PCs and the server are connected by a wireless LAN.

Two departments at the University of Mannheim (Computer Science and Educational Science) have initiated the LectureLab project (http://www.lecturelab.de) to create a new form of multimedia-enhanced teaching: the **interactive lecture.** We have designed and implemented a full-featured software system and carried out several major field studies to evaluate this concept.

In this paper we will:

- describe the possible use of mobile devices in large learning environments;
- present the scenario of the Interactive Lecture, as well as our own technology at the University of Mannheim, WIL/MA (Wireless Interactive Lectures in MAnnheim);
- discuss the results of two detailed case studies conducted among graduate students, focusing on the comparison between the use of PDAs and notebook PCs; and

- give an overview of the results of six experimental field studies we carried out in computer science and educational science lectures in order to investigate the motivational and cognitive effects of this new teaching-learning-method.

MOBILE DEVICES IN LECTURES

Numerous projects focusing on the use of mobile devices in lectures in order to enhance learning and teaching have evolved over the last few years. Most of them have very unique ideas about what aspect of the lecture they intend to improve, and about how to cope with eventual problems. The following is a short list of past and ongoing projects, along with a short description of the basic ideas behind them.

Classtalk (Abrahamson, 1999, 1998; Webking, 1998; Dufresne, Gerace, Leonard, Mestre & Wenk, 1996) is a well-known Classroom Communication System by Better Education Inc.. For the better involvement of every single student, the teacher "beams" three to four Classtalk tasks per lesson to the students' devices; these can be calculators, organizers or personal computers, and the students often own them. A "task" can be anything from a simple question to a midterm exam, from a group exercise to a survey of class opinions. The results are displayed immediately on the teacher's notebook PC; the teacher can either keep them confidential or show them to the class. The class sessions can be archived for review, and can be analyzed and compared to other sessions. Additional features include feedback (from the teacher), tests and grading. Classtalk can also be used for the so-called „peer-instruction"-method, a kind of collaborative learning in which answers to several questions („ConcepTests") are to be discussed in small learner groups (Mazur, 1997).

A questionnaire study by Hake (1998) with more than 6 000 American physics-students showed that interactive learning environments (Classtalk vs. traditional instruction) enhanced the students' capability to solve problems. Abrahamson (1999) could also assess an increase of the knowledge gain if interactive elements were integrated into instruction. Another study, in the Netherlands (Massen, Poulis, Robens, & Gilbert, 1998), showed that with physics students, the integration of the so-called Audience Paced Feedback (APF), a system comparable to the Classtalk system, leads to an enhancement of learning success. Finally, Hartline (1997) stated that using Classtalk improved the reading comprehension of elementary school pupils.

ClassInHand, from Wake Forest University, turns a PDA equipped with a wireless adapter into a presentation controller and a quizzing-and-feedback device for the lecturer (http://classinhand.wfu.edu/, last checked 11/10/04). Its major components are a presentation control application and a web server for the PocketPC of the teacher; the clients only need a web browser to participate. The Presentation Control allows remote control of the Powerpoint slides on the lecturer's PC. It also gives him the possibility to forward the quiz results to the class. The Web Server enables concept tests (quizzes), textual feedback, a feedback meter, and easy document posting. The quiz feature can be used to present a question with up to four answers, and to view the results immediately on the PDA or to forward them to the students' devices. The textual feedback component allows students to send their questions directly to the teacher's PDA. Finally, the feedback meter enables students to submit numeric responses (range: -10 to 10).

ConcertStudeo, a project of the Fraunhofer Institute *IPSI,* uses an electronic blackboard combined with handheld devices (Dawabi, Dietz, Fernandez & Wessner, 2003). It features exercises and interactions, such as multiple-choice quizzes, brainstorming sessions, queries, or role-plays. During a lecture, the teacher introduces the exercise, and the learners enter their answers into their handheld devices. The software does the collection, analysis, and presentation.

Specifically designed for online feedback is *CFS* (the Classroom Feedback System), from the University of Washington (Anderson, Vandegrift, Wolfman & Yasuhara, 2003). It allows students to post annotations directly on lecture slides. The lecturer sees the annotations in real-time. The students use their notebook PCs to generate their feedback by clicking a location on a slide and selecting a category from a fixed menu (such as "more explanation", "got it", "example"). The teacher's screen shows the number of feedback requests for each slide, and displays the aggregated feedback with a shaded dot for each annotation at the actual presentation slide. The slides depict categorical information by colour (e.g., red for "more explanation"), and the slide context by location.

THE WIL/MA SOFTWARE

As shown, there are many different settings and ways to take advantage of mobile devices to improve interactivity in the lecture hall. Most of the earlier work has focused on specific issues, such as quiz only, online feedback only, or annotations only. Furthermore, the software is often designed to run only on a particular hardware device or, in some cases, only on very proprietary hardware. Finally, none of the existing projects features synchronous, bi-directional communication for large classrooms: in most cases, it is only the students who can send data to the teacher at any time, while the teacher cannot send personalized responses.

Our software tools attempt to solve these problems: the same basic software architecture accommodates many different interactivity services. The system is written in Java and is portable to almost all modern mobile devices.

System Architecture

The WIL/MA system is designed as a classical client/server application (see figure 1). As the central part of the architecture, the server provides all the fundamental functionality: management of the connections, users, and services. *Connection management* establishes connections to the clients upon request, processes incoming and outgoing data, and monitors the registered connections for broken links. *User management* identifies individual users via password and stores personal information for internal and external use. *Service management* dynamically loads a requested number of plug-in service modules, informs clients about the availability of certain services, and controls the data flow between the services within the server structure itself and between clients.

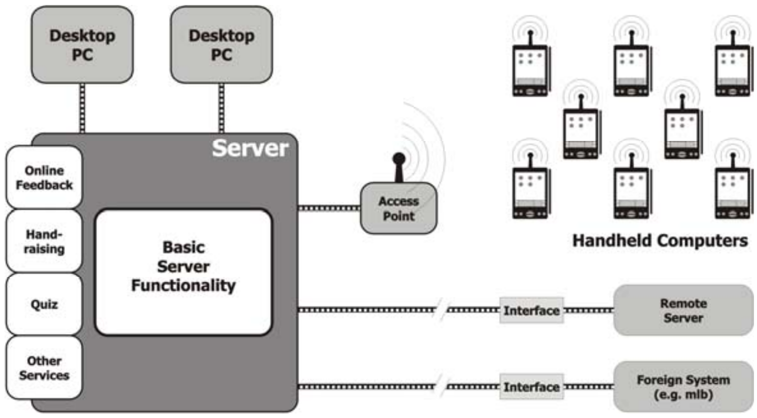


Figure 1: The WIL/MA architecture

All functionality that is visible to the users is bundled into services. Services are built as independent modules to be loaded by the server and the clients at start-up time; for each service, there is a server-module, a teacher-module and a student-module.

The server-modules are the central part of a service. They aggregate all incoming data, analyze the information, and broadcast trimmed data packets in various ways back to the teacher and each individual student. The server software provides a sophisticated messaging system for this purpose. All other modules are loaded into the clients of the students and the teacher. While the teacher-module focuses more on editing various aspects of the service, as well as on the display of analyzed data, it is more important for the student-module to display prepared material appealingly and to provide an intuitive user interface.

The client for the lecturer runs on a machine typically connected to the server via a wired network; all other clients use the wireless LAN to connect to the server. By means of interface utilities, multiple servers can be connected to extend the range of an interactive lecture to other lecture halls easily, without overloading the network in-between. Interfaces to other similar software systems can be created to share data of common services.

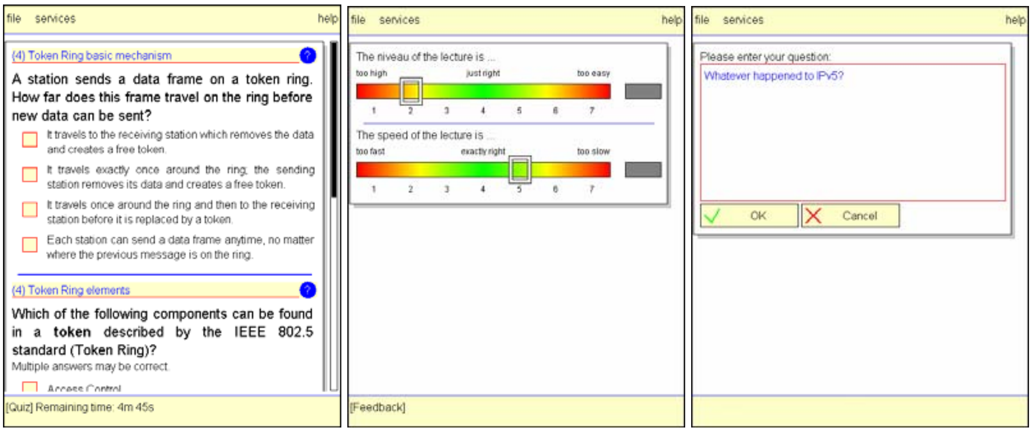
Besides the already discussed functionality, the server software also provides several tools to easily manage a larger number of students' devices. The two most important features are a DHCP server, allowing the central configuration of all network-related parameters, and a Java class server that offers all required Java classes for download. Thus, only a very small footage of classes has to be installed on the students' computers, while all other classes are loaded automatically at start-up. The class server can also be used to update all mobile devices whenever the software is changed (e.g. new releases, updates).

Implemented Services

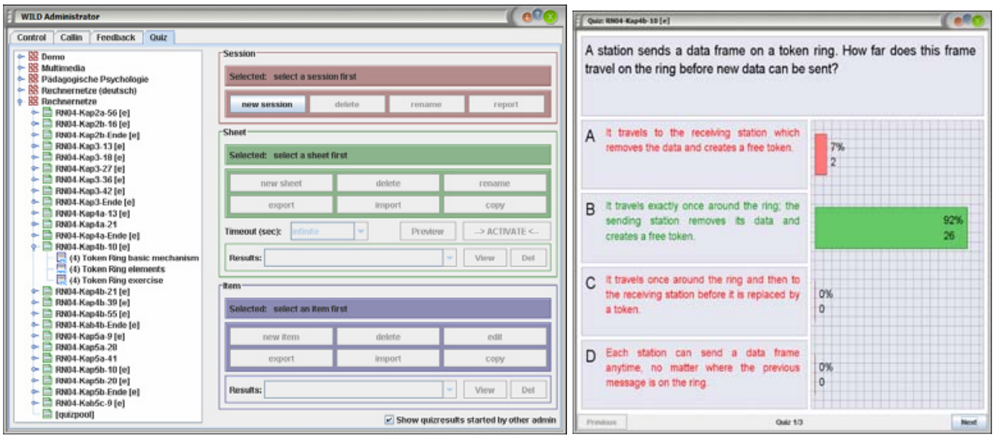
Three services have been implemented so far: a quiz tool, an online-feedback tool, and a call-in tool.

The *quiz tool* allows the teacher to pose questions (that possibly include graphics or animations) about actual lecture contents and “beam” them via wireless LAN to the audience. The students work on them and send their answers back to the lecturer’s computer. After a timeout, the cumulated results are presented graphically on the projector. In this way, the lecturer and the students gain representative feedback on the newly acquired knowledge. Apart from two different multiple-choice question styles (only one correct answer, multiple correct answers), we integrated other optional question types into this service, which can be automatically analyzed. To give some examples: Clickable images can be used to ask the student to point into a certain area of a picture as an answer (for example: "point at the location of Moscow on a map of Russia"). Fill-in questions make it impossible for the student to accidentally guess the right answer to a mathematical exercise.

The *feedback tool* delivers direct and systematic feedback about different aspects of the lecture from all students to the lecturer, who can then instantly adapt his/her presentation style to the new situation. An aspect - or category - could be the speed or the level of the lecture; so students can ask the teacher during the lecture to progress more slowly or to discuss a certain topic in more detail. Technical issues also can be used as a feedback category; for example, video or audio distortions in telepresence scenarios can be discovered much sooner, or the students are able to complain, when their learning environment is suboptimal (because other students in the back rows are too loud ,or bright sunlight makes it impossible to read the projected lecture slides).



Figures 2a, 2b, and 2c: Screenshot of the students' client, showing a quiz, feedback, and call-in



Figures 2d, 2e: Screenshot of the administrator client and a typical quiz result

Finally, the *call-in tool* forwards spontaneous text questions to the teacher at any time during the lecture. The questions are stored in a list and can be dealt with in three ways: using the software, they can either be answered individually, or the answer can be sent to all students if the question is of general interest (of course, the anonymity of the original student is maintained). In these cases, FAQ lists can be created, which are then put on the Web for the next generations of students. The third way is to integrate questions or remarks from students into the lecture. A selection of screenshots from the teacher's client, as well as from the students' client, can be seen in figures 2a-e.

Group Support

From the software-engineering perspective, there are three types of group support to be considered in an interactive lecture: device sharing, working groups and distributed working groups.

Device sharing is particularly interesting in lectures, where many students want to participate but only a limited number of devices are available. In this case, the software could allow multiple students to log in and then select their name before accessing a certain service. This way, each student in a group still acts as an individual, from the server perspective. In quiz rounds, for example, the students could work out their answers on a piece of paper and then use the device only to send them to the server. The ConcertStudeo software is one of the few projects that support device sharing.

Most projects - including WIL/MA - do not because of some severe problems with this feature (for example, the second student in a row can easily copy the answers of his predecessor). Furthermore, the second type of group support is an easy, but feasible, alternative: A group of students collaborates using a single device. The software has not to support this explicitly because there is little difference between a working group and an individual student when using only one login account.

The third type of group support is much more interesting because it offers a wide range of possibilities. In this scenario, students are able to form groups or are put into groups, but still have their own individual device. This way, they can still act individually in some services (feedback or call-in). In other services (quiz, or online brainstorming, for example), the server specifically aggregates the individual input, to form a homogenous group input.

This technique allows the formation of groups over wide distances, connecting students who don't know each other, or in crowded lecture halls, where group members often cannot sit next to each other. The group-building process is also much more interesting: students can advertise their skills in a list and can be invited by a group that lacks these skills. Or groups can be formed automatically using various heuristics, thus bringing together students of equal or complementary knowledge.

Obviously, this kind of group support places high demands on the software system. First of all, the students in a group have to be able to communicate. The communication must be easy to handle, must not disturb other students, and should be blended into the standard screen of the service as seamlessly as possible. During a quiz, for example, the students would see little coloured dots next to the answers that their fellow group members think to be correct. The brighter the dots are, the more confident is that group member of his or her selection. Whenever there is a disagreement, the students can switch back to a VoIP or chat screen to discuss the final answer.

Handling unresolved disagreements is a second demand on the software. The single analysis step of a system that only supports individual input has to forego a pre-analysis step, where heuristics decide the final input of a group in case of discrepancies.

Using the Tools within an Interactive Lecture

To dispatch an interactive lecture, only three devices are needed: a single access point is usually sufficient to handle the connections from more than 100 students. The server software can be run on any computer running Java; if it is installed in the lecture hall, a standard notebook is sufficient. This computer is usually used for the teacher software, as well. Finally, a projector is needed to display the aggregated results of several services (primarily the quiz service) to the audience.

Since most of the lecture halls are already equipped with projectors or large monitors, all equipment needed fits into one notebook travel bag and is installed and started in usually less than 5 minutes before the lecture starts, including the time needed to start the appropriate software.

Of course, it is quite time-consuming to hand out several dozens of PocketPCs to students who do not own a mobile device. This requires some assistance; but in our experience, the students are quite disciplined, and all the devices are usually treated very carefully. Furthermore, more and more students own a PocketPC or Palm or would like to use their notebook in the lecture anyway. Hence, it is most likely that having to provide large pools of mobile devices will no longer be an issue in the very near future.

Once the software is started, the students will begin to log in. In our case, the services: feedback and call-in are started right at the beginning and are thus accessible the whole time. Quizzes are scheduled approximately every 30 minutes. In our interactive lectures, the students thus had two breaks for the quiz rounds in each lesson of about three to four questions, which proved to be very effective. Also, a good practice may be to start with a short quiz, to see what the students have learned in the last lecture. The questions are prepared before the lecture and submitted to the students at an appropriate time during the lecture. Depending on the difficulty of the questions, the students are given three to five minutes to answer them; the discussion of the results usually takes another five minutes.

The results of all services are stored on the machine running the teacher’s client in a portable XML-based format, so that the teacher can analyze the information at any time later.

EXPERIMENTAL FIELD STUDIES AND EXPERIENCES

Altogether, we have conducted six experimental studies to date in order to investigate the motivational and cognitive impacts of this scenario (assessed in the form of questionnaires with respect to acceptance, and through the application of tests with respect to the learning success). Four of the studies were carried out in computer science lectures, and two in education science meetings. A seventh study (in education science) is still running.

In the following chapter, we will give a brief overview of our studies' results, separated by the different faculties where the interactive lectures took place.

Interactive Lectures in Computer Science

First, a test trial (winter semester 2001/2002) of the interactive lecture scenario was carried out (Wessels, Fries, Horz, Scheele & Effelsberg, submitted). In an experimental study (2x2 design), a first prototype of the WIL/MA tools was technically and empirically tested in a computer science lecture by comparing two wireless LAN-supported sessions with two conventional lectures on the same topic. The 44 randomly assigned students at this lecture each participated in both an interactive and in a conventional lecture session, then the groups were compared with respect to acceptance of the teaching method (questionnaire based on 13 items) and success in learning (pre-post measures). Regarding the acceptance, the interactive condition was evaluated significantly better than the conditional one (p<0,001; η^2=0.433, respectively 0.325).Students also reported significantly higher levels of assumed attention, activity, and estimated learning success in the interactive condition (p<0.001). Objective measurements indicated better learning results in the interactive condition, though the values fall just short of significance (p=0.068, η^2=.081). And finally, there was no meaningful distraction during the interactive lectures.

As the next step, in summer semester 2002, a long-term integration of the system was realised, as well as an application of the scenario within a tele-lecture (Scheele, Mauve, Effelsberg, Wessels, Horz & Fries, 2003). The investigated computer science lecture was transferred as an MPEG-stream via the internet to a lecture hall at another German university. Just like the students in Mannheim, the students at the remote location were included into the scenario and the study. The lecture was temporally split into a conventional and an interactive phase[1], the latter of which was composed of eight consecutive sessions. For all 99 students participating in these two conditions, the acceptance of the two teaching methods (as measured in the first study), and their learning increases (pre-post measures) were quantified. We could replicate the good acceptance scores of the first study: again, the interactive meetings were rated very well and their acceptance was superior to that of the conventional lecture (p<0.005, η^2=0.332). The use of the interactive elements/tools had a highly significant effect on the knowledge acquisition in the respective lecture. The participants in the interactive lecture had a significantly higher and also faster learning increase (see figure 4) in comparison to those in the conventional sessions.

In the next summer semester (2003), a variation of feedback to the quiz rounds (i.e. the discussion of the results) within an interactive computer science lecture was performed in another quasi-experimental study (Wessels, Fries, Horz & Hofer, 2003). The investigated computer science lecture was realized as an interactive meeting over the entire semester and was again transmitted as a tele-lecture. Within the lecture, a systematic temporary variation of the information capacity of the quiz feedback was realized. There were three conditions, whereby the verbal feedback from the teacher to the quiz rounds differed in each condition, becoming more and more informative over time. The 56 students were compared with respect to their acceptance of the lecture and the three feedback methods, and their respective learning increases. The study results show that the interactive lecture was once again highly accepted. Moreover, the students prefer an elaborated feedback to the quizzes that is related to information about the correct and incorrect solutions (see figure 5). Regarding the learning increases in each condition, the highest increases could be seen when feedback was given that included further information about the solutions (condition 2 vs. 1: p<0.001, condition 3 vs. 1: p =0.002, condition 2 vs. 3: not significant).

The aim of the fourth interactive lecture (summer semester 2004) was a realisation within a computer science course as close as possible to the reality in higher education. Therefore, the accompanying evaluation was kept as unobtrusive as possible: only at the beginning and at the end of the semester were measurements with respect to the knowledge and acceptance of the scenario and the tools carried out. Furthermore, we tested the WIL/MA group support tools for the first time. In contrast to the other studies, the 69 participating students were equipped with mobile computers for the duration of the semester. These were distributed at the first lecture of the semester and returned at the final lecture. Initial results for this scenario indicate a replication of the earlier good acceptance, as well as of the better learning success of the students who visited the lecture as opposed to those students who did not participate (e.g. just learned on the basis of the lecture recordings). Especially those students who participated in the interactive lecture in groups attained better examination results at the end of the lecture.

In summary, our results for interactive lectures carried out with computer science students show that:

[1] Due to the fact that the study took place within a real lecture over the entire semester, a quasi-experimental approach was realized to enhance the ecological validity. See Cook & Campbell (19979) for further information about the limits of quasi-experimental designs.

1. The students highly accept the interactive lecture.
2. Learning efficacy increases through the use of the interactive tools.
3. Regarding the feedback on the quizzes, students prefer informative feedback on the quiz rounds (which includes further information about the quiz solutions), which leads to greater learning success.

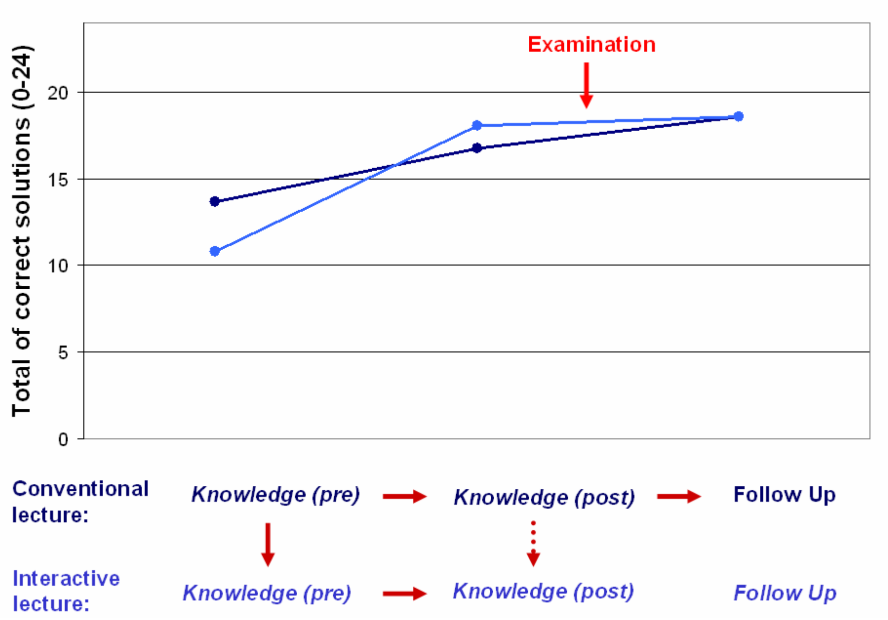


Figure 4: Study in Summer Semester 2003: Learning Increase
Note: arrows represent significant increases (continuous lines: p<.001; dashed line: p<.05).

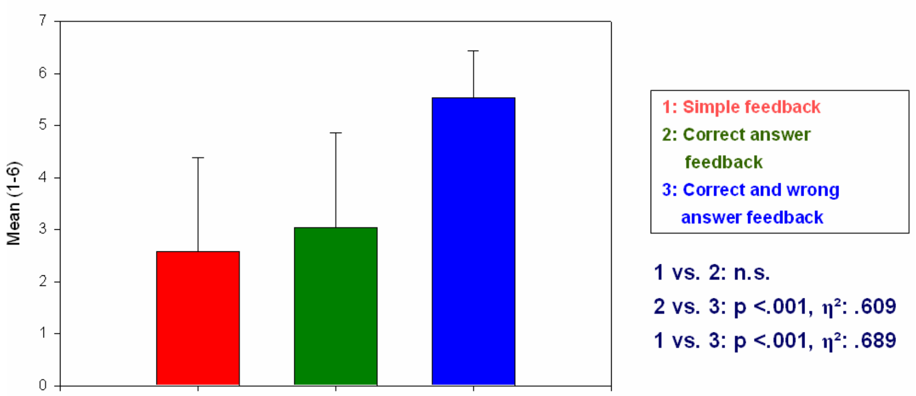


Figure 5: Study in Summer Semester 2003: Acceptance of the Feedback Conditions
Note: n.s.: not significant

The next step was to carry out interactive lectures with participants - and a lecturer - who have less technical experience than computer science students. In order to generalize previous findings and to extend the research by investigating a technically less experienced sample, we implemented the scenario within an education science lecture.

Interactive Lectures in Educational Science:

In an education science lecture (winter semester 2003/2004), our research focused on the questions whether and how a variation of individual feedback on the quiz performance will affect cognitive and motivational variables. Of the 214 participants at the lecture, 69 were equipped with mobile computers per random assignment. The other students participated in the interactive sessions using a pencil & paper-based procedure. Additionally, the users of a mobile computer received personal feedback about their actual learning outcome in the quizzes via their mobile devices. This feedback was systematically varied between and within the groups with respect to the effects of different reference norm orientations (individual vs. social vs. none). The first results show, in terms of motivational factors, a very good acceptance of the scenario, independently of the manner of participation over the entire semester. Furthermore, all students were concentrated, and rated the actual lesson as being of more than average interest. With respect to the learning outcome, the variation of the reference norm orientation on the quiz feedback shows an advantage in favour of feedback under the use of an individually oriented reference with respect to the learning outcome, as opposed to a socially referenced feedback (p=0.018, η^2=0.101 to p=.082, η^2=0.056), although both types were accepted equally well. Furthermore, the results show that in both user groups: PocketPC vs. paper & pencil, the learning increase is significant (p<0.001, η^2=0.510 for the PocketPC group, respectively: p<0.001; η^2=0.589 for the paper & pencil group), and was stable over a period of one month after the end of the lecture. Concerning quiz performance, computer-based participation in the quizzes yielded greater learning success (p<0.001). Additionally, the learning increase, as measured by a pre/post measurement, also was higher if a PocketPC was used (p=0.034; η^2=0.041). In general, this study shows that the interactive lecture can be integrated in a non-technical faculty also.

CONCLUSION AND OUTLOOK

Conventional mass lectures entail various serious didactic problems with respect to cognitive and motivational conditions for learning. Their main disadvantage is that there is little or no interactivity between teachers and students. The students' attention and motivation – and as a consequence thereof – their learning success, are negatively influenced, as is the teacher's ability to react to their remarks.

In order to optimize education in mass lectures, we have started the LectureLab project. The idea was to support synchronous interactions between students and teachers by the use of mobile computers in a wireless network (teaching–learning scenario of the interactive lecture). All students are equipped with handheld computers and use several wireless interactive learning services that enable feedback in both directions (to realise bi-directional, synchronous communication).

Our experiences show that with respect to the technical realisation, an interactive lecture is very easy to implement. Concerning the use of different mobile devices within this scenario, we strongly prefer PocketPCs and Notebooks.

The experimental field studies show that an interactive mass lecture that involves the use of mobile computers strengthens the learning process in higher education essentially. Particularly for mass meetings, wireless networks (together with an appropriate didactic concept) are a new and promising opportunity to actively include the students into the process of learning. Apart from promoting students' attention and motivation, a key point is that this scenario also supports the learners' acquisition of knowledge. Thus, the interactive lecture seems to be a successful effort to improve a dominant university instructional technology.

In the future, lectures will definitely not become obsolete in higher education in Germany or most other countries worldwide. Thus, an enrichment of this dominant teaching method around interactive and adaptive elements will be a persistent optimization. All faculties can use the technology to transform traditional lectures into interactive lectures as long as the learning content is to be mediated in lecture methods and there is a big audience (i.e. mass meetings). Because of the flexible application of the hard- and software, as well as the adaptive didactic concepts, no structural changes in the system of higher education are necessary. If interactive lectures are to be immediately integrated in different disciplines, the presence teaching can be strengthened by the creation of an individually flexible frame model. At the same time, the problem of the "mass lecture" diminishes as to its negative didactic consequences. By means of an interactive lecture, it is generally possible to directly integrate new media into higher education in a didactically meaningful and technically economical fashion.

Nowadays, it is still necessary to equip the students with mobile devices. With respect to the hardware, one can assume that the distribution of mobile computers (PocketPCs) will increase rapidly in years to come. In the future, most of these devices will be able to communicate over radio, so the availability of this scenario will increase.

Group support will be a major issue for the next releases of the WIL/MA software and in subsequent field studies. The first steps in that direction have been taken, with an early prototype for collaboration in quizzes and an ongoing project that uses WIL/MA for participatory simulations.

Future research should also include the role of the teacher within this scenario. Even though the students obviously benefit from this new technology, and the teacher gets additional information about their learning processes and progress, the additional integration of interactive elements increase the cognitive load upon the lecturer. This may be especially a problem for teachers with no affinity for technology. Therefore, an important question is how to deal with the rising demands: What is the appropriate extent of information from the learners? Which kind of adaptive behaviour should occur in form and content, as well as with respect to the point in time of adaptivity (direct vs. indirect)?

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The Impact of Role Assignment as Scripting Tool on Knowledge Construction in Asynchronous Discussion Groups

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Abstract. The present paper describes the impact of learning in asynchronous discussion groups on students' levels of knowledge construction. Multilevel analyses were applied to uncover the influence of student, group, and task variables and the specific impact of the assignment of roles. Results indicate that students' attitude towards the learning environment and their engagement in the discussion group are significant predictors. No significant overall differences in students' mean levels of knowledge construction between the role and no role condition were observed. However, additional analyses revealed (1) that students in the role condition more often reached the highest level; and (2) that assigning students the role of summarizer resulted in significantly higher levels of knowledge construction.

Keywords: CSCL, collaborative learning, asynchronous discussion groups, roles, scripting

INTRODUCTION

Computer-supported collaborative learning (CSCL) environments have been argued to foster collaborative knowledge construction (Clark, Weinberger, Jucks, Spitulnik, & Wallace, 2003). Collaboration as such, however, does not systematically produce learning (Dillenbourg, 2002). Research evidence shows that the efficacy of collaborative learning depends on various conditions such as group composition (e.g., size, gender), task features (e.g., task complexity), and individual student characteristics (e.g., learning styles, attitude towards the learning environment) (Schellens & Valcke, in press; Schellens, Van Keer, & Valcke, 2004). These conditions interact with one another in a complex way. Moreover – despite their impact – it must be taken into account that not all these variables can be manipulated directly while designing CSCL environments. Instead of changing the conditions that indirectly determine the group interactions (e.g., group size, heterogeneity of group members), in the present study we especially focus on variables that can be manipulated to influence students' interactions in a direct way. More specifically, we try to **script** students' discourse in CSCL environments. This aim corresponds to the suggestion of Dillenbourg (2002) who claims that the application of scripts for collaborative learning can be a technique to affect collaborative learning directly. Collaboration scripts can specify, sequence and assign collaborative learning activities in on-line learning environments (Kollar, Fischer, & Hess, 2003; Weinberger, Reiserer, Ertl, Fischer, Mandl, 2003). The concept of 'script' however encompasses a very broad range of methods, techniques and approaches. In this respect, it is difficult to speak about the overall efficacy of CSCL scripts. The aim of the present study is to analyze the impact of a specific type of collaboration script, namely the assignment of **roles** to group members in asynchronous discussion groups.

CONTEXT OF THE PRESENT STUDY

The present study was conducted in a naturalistic research setting. The asynchronous discussion groups were a formal component of a 7-credit, first year university course 'Instructional sciences', which is part of the academic bachelor's curriculum 'Pedagogical Sciences' at Ghent University. This freshman course introduces students to a large variety of complex theories and conceptual frameworks related to learning and instruction.

All students taking the course (N = 286) participated in the study. The discussion groups were set up in parallel to 12 weekly face-to-face sessions. Participation to the discussion groups was obligatory and evaluated.

Twenty-five percent of the final score for the course was based on the quality of individual student participation to the electronic discussion groups.

THEORETICAL EXPLORATION OF THE VARIABLES INVOLVED

In order to understand the entire story of learning in a CSCL environment we need to consider variables at different levels.

Regarding the importance of **characteristics of individual students**, there is little research evidence about their specific impact in the CSCL field. Variables such as gender, age, and appreciation towards the learning environment are rather considered as background variables. Hakkarainen and Palonen (2003) for example report about the impact of gender on students' interest in CSCL and how this influences learning outcomes. Other research indicates that learners who are motivated and engaged, tend to learn more than those who are not (Reio & Wiswell, 2000). Engagement and contributing to the discussion appear to be mutually interrelated: motivated students are likely to participate more in CSCL environments, which leads to higher levels of knowledge construction (Schellens et al., 2004). Learners generally are more engaged and motivated when the learning mode is compatible with the ways in which they cognitively process information (Sternberg, 1997). Workman (2004) more specifically suggests that design researchers should consider the learning styles of the students and provide fitting learning environments when possible. Schellens and Valcke (2000) also observed that consistency between the requirements of the on-line learning environment and learning styles is important. In the same study they also pointed at the importance of student satisfaction, which interacts with the impact on knowledge construction.

Taken into account the empirical grounds of the aforementioned student characteristics, the following variables will be considered in the theoretical base of the present study: gender, learning styles, attitudes towards the CSCL environment, and engagement in the discussion, which will be operationalized as the individual amount of messages contributed to the discussion group.

In relation to **group characteristics**, prior research has stressed the importance of fostering intensive group interaction (Dillenbourg, Baker, Blaye, & O'Malley, 1995; Schellens & Valcke, in press; Schellens et al., 2004). Studies more specifically report that an increase of the amount of discourse promotes learning (e.g., Jeong & Chi, 1997; Mäkitalo, Weinberger, Häkkinen, & Fischer, 2004). Some of these authors also point at the relationship between interaction levels and group size. Group size should not be too large, since larger groups do not provide the opportunity for all members to participate in full. On the other hand when groups are too small, there is not enough interaction to provide a critical amount of exchange of ideas or information in order to come to higher levels of knowledge construction (Johnson, Johnson, & Holubec, 1998; Slavin, 1995). In this respect it is also logical to assume that the number of students depends on the requirements of the collaborative learning task (Kumar, 1996). In addition to level of interaction and group size, the literature also goes into the issue of group composition as a critical characteristic. Research results, however, are less conclusive and come to contradicting results. Some studies emphasize heterogeneous groups (Johnson et al., 1998; Nurrenbern, 1995; Slavin, 1995), while other studies contradict these research results (Felder, Felder, Mauney, Hamrin, & Dietz, 1995).

In the context of the present study, group size will be kept constant (10 to 12 students per discussion group) and group composition will be randomized, to obtain heterogeneous groups. Intensity of the group interaction will be measured and used as an interaction variable.

With regard to **task characteristics**, recent CSCL research suggests that a clear task structure is needed to foster cognitive processing and academic performance (Dillenbourg, 2002; Weinberger, 2003). Other research points at the need to state directions, guidelines, and specific types of expected cognitive processing (Cifuentes, Murphy, Segur, & Kodali, 1997; Harasim, Hiltz, Teles, Turoff, 1998; Schellens & Valcke, in press). Hakkarainen, Lipponen, and Järvelä (2002) also indicate the need to prompt students to articulate their conceptual understanding to promote learning and knowledge building. These prompts are also called collaboration scripts.

As stated above, there is a broad range of approaches that fit the description of collaboration scripts. One of the potential ways of imposing structure on learners' collaboration is the use of roles. Roles can be defined as more or less stated functions, duties, or responsibilities that guide individual behavior and regulate intra-group interaction (Hare, 1994). Roles appear to stimulate group members' awareness of the overall group performance and each member's contribution (Strijbos, Martens, Jochems, & Broers, 2004). In addition, according to Aviv (2000), certain roles are required to bridge over periods of silence or too silent participants. Advocates of a more structured learning approach generally assert that assigning roles to group members results in more rapidly and more consistent levels of interaction, while others contend that less structure stimulates more elaborate and critical dialogue. According to Rose (2002), assigning roles and providing close monitoring of group interaction creates learning advantages in the short term. However, small groups may approach similar levels of productive interaction in the long term without the added instructional expense.

In addition to scripting students' interaction by assigning roles, another important task characteristic brought up in the literature is the extent to which the assignments link up with students' Zone of Proximal Development. Illera (2001) states that motivation to work collaboratively on a task and the zone of proximal development are intertwined. He observed that when the task exceeded the abilities of the students, their interest and involvement reduced. This brings us to a second task characteristic: task complexity. This issue has hardly been studied in the context of CSCL. Harper, Squires, and Mc Dougall (2000) indicate that task complexity is necessary to provide authentic learning environments. But they also stress that too much complexity can make learners feel insecure and lose track of learning objectives. Research has stressed the need to present tasks or assignments that are within a 'zone' that matches the learner's abilities (Schellens et al., 2004; Quinn, 1997). In the case of too complex task, students did not engage in the discussion, while in the case of rather simple tasks, students were not interested to discuss the matter.

More research is, however, needed to get a better understanding of the impact of these task characteristics. Therefore, the use of roles and task complexity will be considered as key research variables in the present study.

THEORETICAL FRAMEWORK OF THE PRESENT STUDY

Figure 1 presents a graphical representation of the theoretical base for the present study. This is an extension of the approach adopted in previous research (Schellens & Valcke, 2002). It integrates social constructivist principles and concepts derived from the information processing approach to learning.

The key dependent variable in the theoretical base is students' 'levels of knowledge construction' as reflected in the group discussion contributions. Independent variables are described in the following paragraphs.

The figure depicts three key substructures: (1) the individual learning process of a student, (2) the task put forward in the CSCL environment, and (3) the collaborative dimension in the CSCL setting. The learning process of an individual student (*student a*) is presented at the center of the figure. 'Learning' is considered as an information processing activity, building on the assumption that learners engage actively in cognitive processing in order to construct mental models. In this way, new information is integrated into existing cognitive structures.. Because of the importance of individual experiences and existing cognitive structures, characteristics of the individual learner, such as attitude towards the CSCL learning environment, gender, and learning styles are considered of importance. Moreover, it can be hypothesized that the more students express their line of thought, the more the construction of mental models is facilitated. Therefore, student engagement in the discussion (i.e. the amount of individual contributions) is regarded as relevant.

A second substructure points at the impact of the task put forward in the learning environment and discussed in the CSCL setting. The student assignments in the discussion groups are assumed to trigger the cognitive processes of the individual students. The amount of imposed structure in the discussion, that is discussing with or without roles assigned to the students, and the complexity of the task are considered to influence the nature of the cognitive activities. This results in varying levels of knowledge construction.

Finally, a third substructure refers to the importance of the group in the CSCL setting. An important characteristic in this respect is the intensity of the group interaction. The task is put forward in a collaboration environment. This invokes *collaborative learning* that builds on the necessity of the learner to organize output that is relevant input for the other learners (*student a to n*). The exchange at input and output level is considered to reflect a richer base for the further cognitive processing at individual level. This assumption is central in the cognitive flexibility theory of Spiro, Feltovich, Jacobsen, and Coulson (1988). The more exchange at input and output level, the more knowledge construction that can be realized. The output is a central element in the theoretical base of the present study. The asynchronous nature of the discussion environment forces the learner to communicate the output in an explicit way. All the written communication in the CSCL environment is therefore considered relevant. The student output mirrors their cognitive processing activities. Individual processing is slowed down by the complex nature of the tasks since learners have to cope with selection, organization, and integration processes. As a consequence, learners experience the *limited capacity* of their working memory, also referred to as *cognitive load* (Sweller, 1994). However, learners in a collaborative setting can profit from the processing effort of other group members. Since the output of other learners is organized, students are expected to experience lower levels of cognitive load when using this output as input for their own individual cognitive processing. This subsequent output is expected to be of better quality, thus reflecting a higher level of knowledge construction. In the present study, we build on the work of Gunawardena, Lowe, and Anderson (1997) to identify students' levels of knowledge construction. This analysis and coding system will be used to analyze the transcripts of the written communication and to determine students' individual levels of knowledge construction. At a more basic level, the coding will also identify whether the discussion input is task-oriented or not task-oriented. This distinction is derived from the work of Veerman and Veldhuis-Diermanse

(2001). Task-oriented communication input can be coded further following the levels of knowledge construction as distinguished by Gunawardena and her colleagues (1997).

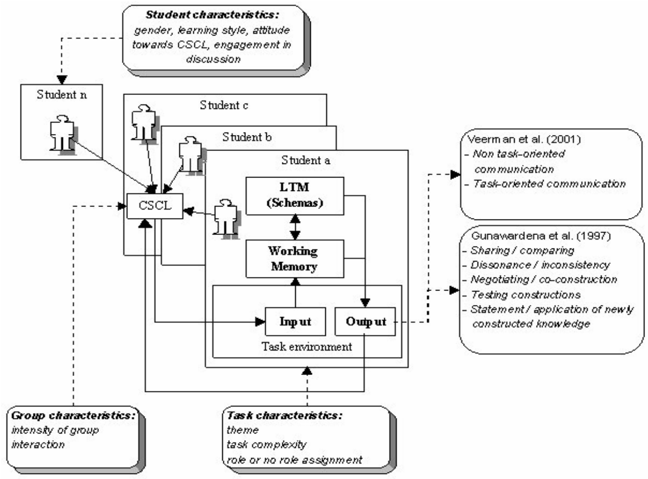

Figure 1. Graphical representation of the theoretical framework

According to the theoretical framework, learners construct knowledge by active participation in discussing and sharing knowledge with their peers when working in small groups. Students actively engage in learning processes when working jointly on a learning task by mutually explaining the learning contents, giving feedback to other group members, asking and answering questions, etc. (Weinberger, 2003). However some groups encounter difficulties when engaging in activities of collaborative knowledge construction. Numerous studies indicate that the desired effects often fail to emerge. Research for instance indicates that not all group members are actively engaged in the discussions (Salomon & Globerson, 1989) or that the content of the group discussions remains superficial (Coleman, 1995). Reasons for these deficits can result from characteristics of the individual students or from characteristics of the group, but can also be due to the unique character of the task. The focus in the present research will be especially on the task characteristics and more specifically on the impact of task complexity and the use of roles. Considering the theoretical framework, student and group characteristics will also be taken into account in the analyses, since we suppose they interact with one another and influence the dependent variable ‘level of knowledge construction’.

PROCEDURE

All students (N = 286) enrolled for the course ‘instructional sciences’ were randomly assigned to a discussion group (N = 23). Each group consisted of about 12 students.

An experimental design was adopted with the entire first-year student population being randomly assigned to the discussion groups. More specifically, two research conditions can be distinguished: students in the discussion groups did or did not receive role assignments. Informed consent was obtained of all students.

After a trial discussion session of three weeks, students participated in four consecutive discussion themes. The entire treatment lasted 4 months. Within the three-week time frame students were flexible as to time and place to work on the discussion assignments. After three weeks, student no longer had access to the particular theme and a new discussion theme was presented.

During the first face-to-face session of the semester, the objectives of participation in the discussion were communicated to the students, at the same time, a demonstration was given of the CSCL environment. A number of strict rules, were stated. At the start and at the end of the course, a number of instruments were presented to the students. In this way, data was gathered with regard to the student characteristics age, gender, and educational level. During the first administration, a special section was added to measure students’ attitude towards the task-based learning environment and their attitude towards participation in the discussion groups. Furthermore, the Approaches and Study Skills Inventory for students (ASSIST) was presented to gather information about students’ ‘learning styles’ (Entwistle, Tait, & McCune, 2000). Reported reliability for the ASSIST is high, with Cronbach’s α between .80 and .87.

The information about the group characteristic ‘intensity of interaction’ was derived from the analysis of the contributions to the discussion groups (see infra). The task characteristic ‘task complexity’ will be explained when describing the discussion themes.

Students worked together in the discussion groups by applying the theoretical concepts of the course to solve problems, which were presented in the on-line environment. These problems were, in line with the constructivist principles, based on real-life authentic situations. For a more detailed description of the kind of discussion assignments see the research of Schellens and colleagues (2004).

Task complexity was determined for each task in the discussion groups. The degree of complexity of the tasks showed a strong upward trend in the second and third assignment, while the fourth assignment was again less complex.

The nature of the discussion assignments was the same for all 23 discussion groups in the research, regardless of the research condition the groups were in: the same learning goal, context, inquiry expectations, time requirements, and deliverables were put forward. The experimental treatment was based on whether roles had been assigned or not. Students in 15 out of 23 discussion groups were assigned specific roles. Four different roles were distinguished: 'moderator', 'theoretician', 'summarizer', and 'source searcher'. These roles were assigned randomly to 4 students in each group. At the start of every new discussion assignment, the roles were assigned to 4 other students within the same group. This is in line with a collaboration script proposed and tested by O'Donnell and Dansereau (1992).

The 'moderator' closely monitored the discussions in the on-line environment (every 2 or 3 days) and interjected praise, offered advice, answered questions, and posed critical questions. This student stimulated active group participation. The 'theoretician' had to make sure that all appropriate theories were considered when tackling the task and had to indicate which aspects, relevant theoretical knowledge, or information was lacking. The 'summarizer' summarized the contributions and initial solutions of the students in the discussion groups. This student had to indicate the different points of view and had to try to make some provisional conclusions. The 'source searcher' looked for additional sources and further information, so that students were prompted to look further than the content of the available course reader.

HYPOTHESES

The present research aims to observe the differential impact of assigning discussion roles to students on their level of knowledge construction. In addition, the impact is studied of variables at the level of the student, the group, and the task. The following hypotheses present step-by-step sub-questions in relation to this general research questions.

Impact of student characteristics:

- More intensive and active participation in the discussion groups is positively related to students' level of knowledge construction.
- Students with a positive attitude towards the on-line learning environment will reach significantly higher levels of knowledge construction.
- Students with a deep or strategic learning style will obtain significantly higher levels of knowledge construction.

Impact of group characteristics:

- Being part of a group with intensive discussion activity will lead to significantly higher individual levels of knowledge construction.

Impact of task characteristics:

- The complexity of the task has a significant impact on the level of knowledge construction.
- Working in the role condition will have a significantly positive impact on students' levels of knowledge construction.

ANALYSIS OF THE TRANSCRIPTS OF THE DISCUSSION GROUPS

The transcripts of eight groups were randomly selected from the larger data set. For each of the eight groups, the complete communication submitted in relation to the four discussion themes was used for analysis purposes using the scheme of Gunawardena and colleagues (1997). This content analysis scheme has been developed following a grounded theory approach. It proposes a typology to evaluate knowledge construction through social negotiation. The authors developed an interaction analysis model that discriminates between five phases in the negotiation process during a learning process. Every phase corresponds to a typical level of knowledge construction. In the long run, every learner is expected to reach the highest phases in the negotiation process, thus reaching the highest level of knowledge construction.

In the present research the complete message was used as the unit of analysis. According to Rourke and colleagues (2001) this choice presents some advantages. Firstly, it is objectively identifiable: multiple coders can agree consistently on the total number of units. Secondly, it produces a manageable, controllable set of cases. In the case of the present study for example, we recorded a total of 1933 messages. The third advantage is the fact that we are dealing with a unit which parameters were determined by the author of the message.

To establish inter-rater reliability we used the following method: three independent researchers carried out the coding task. After the coding of each complete transcript of a discussion by the individual coders, the quality of the coding was assessed by determining percent agreement measures. A value of .70 was put forward as a criterion for inter-rater reliability. The initial value was .85. After negotiations percent agreement was .91. To check whether it was not always the same researcher changing the coding category, percent agreement was also calculated for each individual researcher. The latter represents the agreement between the first and second coding of a unit of analysis. Intra-rater reliability always exceeded .70.

RESULTS

Because in the present study the students are divided in a number of groups, the problem under investigation has a clear hierarchical structure. Because of the joint modeling of individual and group variables, we took a multilevel modeling perspective on analyzing the data, for these models are specifically geared to the statistical analysis of data with a clustered structure. To analyze the data, MlwiN for multilevel analysis was used (Rasbash et al.,1999).
To test the hypotheses regarding the impact on students' levels of knowledge construction students' 'mean level of knowledge construction' per discussion theme was used as a dependent variable.

The first step in the analysis was to examine the results of a fully unconditional three-level null model (Model 0). The intercept of 1.95 in this model simply represents the overall mean of the level of knowledge construction according to the 5-level coding scheme of Gunawardena and colleagues (1997). As can be inferred from Model 0, the overall variability in the mean level of knowledge construction per discussion theme can be attributed for the most part (96.20%) to discussion theme-level factors (differences between the four assignments), for 3.26% to differences between students within the groups, and only for a small part (0.54%) to group-level factors (differences between the groups). This is already an important result implying that the differences between the diverse groups and students are much smaller than the differences in individual students' levels of knowledge construction between the different assignments. This entails that the features of the assignment will be of central importance in the further analysis.

To gain a clear insight into the development in students' levels of knowledge construction from discussion theme 1 to theme 4, the measurement occasions were added to the fixed part of the model (Model 1). As can be seen in Table 1 a significant change in levels of knowledge construction could be determined for the second ($\chi^2 = 11.06$, $df = 1$, $p = .000$), the third ($\chi^2 = 13.26$, $df = 1$, $p = .000$), as well as for the fourth theme ($\chi^2 = 8.78$, $df = 1$, $p = .003$). For these discussion assignments a significant decrease in students' mean levels of knowledge construction is observed as compared to the first assignment.

Table 1
Summary of the model estimates for the three-level analyses of students' levels of knowledge construction

	Model				
Parameter	Model 0	Model 1	Model 2	Model 3	Model 4
Fixed					
Intercept	1.95 (0.05)	2.21 (0.08)	2.18 (0.07)	2.17 (0.01)	2.19 (0.08)
Theme 2		-0.34 (0.10)	-0.36 (0.09)	-0.36 (0.09)	-0.41 (0.08)
Theme 3		-0.38 (0.10)	-0.41 (0.09)	-0.41 (0.09)	-0.40 (0.08)
Theme 4		-0.31 (0.10)	-0.21 (0.09)	-0.21 (0.09)	-0.25 (0.08)
Amount of messages			0.06 (0.02)	0.06 (0.02)	0.05 (0.01)
Attitude towards learning environment			0.03 (0.01)	0.03 (0.01)	0.02 (0.01)
Role condition				0.02 (0.08)	
No role assignment in role condition					-0.02 (0.07)
Moderator					-0.25 (0.12)
Theoreticus					-0.16 (0.13)
Source searcher					-0.67 (0.14)
Summarizer					1.08 (0.13)
Random					
Level 3					
σ^2_{v0}	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.01 (0.01)
Level 2					
$\sigma^2_{\mu0}$	0.02 (0.03)	0.02 (0.03)	0.04 (0.02)	0.04 (0.02)	0.02 (0.02)
Level 1					
σ^2_{e0}	0.53 (0.05)	0.50 (0.04)	0.35 (0.04)	0.35 (0.04)	0.25 (0.03)
$\sigma_{e0eappr.}$			0.04 (0.01)	0.04 (0.01)	0.02 (0.00)
$\sigma^2_{eappr.}$			0.01 (0.00)	0.01 (0.00)	0.00 (0.00)
Deviance	838.52	821.98	591.25	591.21	487.08

Note. Values in parentheses are standard errors.

As a next step in the analyses, explanatory variables were included in the model. In Model 2, it can be seen that both student and task characteristics significantly influence students' mean level of knowledge construction. At student level, higher individual number of postings and a positive attitude towards the learning environment result in higher mean levels of knowledge construction. At task level, especially the complexity of the assignments affects students' mean level of knowledge construction per theme. In particular, it appears that the reported significant decrease in mean levels of knowledge construction from the first to the subsequent themes disappears when correcting for task complexity. Structuring the task by assigning roles to students does not have an overall significant impact on the mean level of knowledge construction. Students who were asked to take up the role of 'theoretician' or 'moderator' did not score differently as compared to students who worked in groups without role structuring. Students who were assigned the role of 'source searcher' or 'moderator' scored significantly lower. However, students who had to summarize the discussion at various moments obtained significantly higher mean levels of knowledge construction. Finally, as to the effect of group level variables, the research findings revealed no significant impact of the intensity of the group's interaction on students' mean levels of knowledge construction.

In order to unravel the discourse taking place in the different research conditions, additional analyses were carried out to take a closer look at the differences in the discourse between the discussion groups with and without roles assigned. More specifically, we focused on the following questions:

- Is there a difference in the proportion of task-oriented versus non-task-oriented communication under the two research conditions?
- Is there a difference in the distribution of the different levels of knowledge construction under the two conditions?
- Are there differences with regard to the changes in students' levels of knowledge construction over time for the different conditions?

Chi square analyses were used to explore potential differences in the distributions within the research conditions. Mann-Whitney U-tests were used to test for differences between the role and no role condition.

Is there a difference in the proportion of task-oriented versus non-task-oriented communication under the two conditions?

The amount of task-oriented messages far outweigh the amount of not task-oriented messages in both the role (X^2 = 992.88, df = 1, p =.000) and no role condition (X^2 = 341.88, df = 1, p =.000). By comparing both conditions, using Mann-Whitney U, no significant difference can be noticed (Z = -1.45, df = 1, p = .148).

Is there a difference in the distribution of the different levels of knowledge construction under the two conditions?

To explore the differences between the two research conditions, we first analyzed whether the amount of messages in the five levels of communication are equally distributed in both conditions. No equal distributions are observed for both conditions. This is confirmed by the Chi-Square analysis for both the role (X^2 = 1397.24, df = 4, p = .000) and no role condition (X^2 = 470.29, df = 4, p = .000). More specifically, in both conditions level 1 and level 3 communication types were observed to a significantly higher extent, whereas level 4 and 5 have hardly been observed.

If we compare both research conditions using the Mann-Whitney U-test, no significant differences can be noticed for the mean levels of knowledge construction reached under both conditions (Z = -0.23, df = 4, p = .82) although it appears that the distribution of proportions over the five levels is not quite similar (X^2 = 572.64, df = 4, p = .000). Correspondence analysis revealed that the differences are mainly found in the three higher levels and more especially in the highest level of knowledge construction. In the role condition students more often reached the highest level of knowledge construction, which was however at the expense of messages in level 3 and 4. No significant differences were found with regard to the percentage of messages situated in level 1 and 2. In summary, the findings indicate that, regardless the research condition, numerous contributions were situated at the lower levels of knowledge construction.

Are there differences in the changes over time for both conditions?

Findings reflect a certain decrease in communication reflecting higher levels of knowledge construction for both conditions.

In the role condition, there is an increase of level 1 knowledge construction, which was at the expense of a decrease in messages situated at level 2 to 4. However, there is an increase in level 5 knowledge construction. This change in proportions is significant (X^2 = 51.18, df = 4, p = .000). Correspondence analysis indicated that the changes in proportions of level 3 and 5 were not significant. However, there are significant proportion changes for level 1, 2, and 4.

In the no role condition a different picture arose. There were shifts in the distribution of proportions, but these were not similar to the changes in the role condition. Level 1 communication increased over the discussion themes, while there was a decrease in the amount of messages situated at level 2. Clearly different as compared to the role condition was that the communication situated at level 3 increased, while there was a complete drop of messages in level 4 and level 5. This overall change in proportions is significant (X^2 = 36.52, df = 4, p = .000). Correspondence analysis showed that the most significant distribution changes were situated at level 2 to 4.

In conclusion, it can be argued that there is a change in students' levels of knowledge construction over time. However, the changes are different in both research conditions.

DISCUSSION AND CONCLUSION

The results indicate that a large part of the overall variability in levels of knowledge construction can be attributed to task characteristics.

As to the impact of student characteristics, the amount of individual contributions is a significant predictor for the level of knowledge construction. The level of knowledge construction is also significantly influenced by the attitude towards task-based learning and the attitude towards the group discussions. Accordingly, it can be concluded that the first two hypotheses about the impact of student characteristics can be accepted. More intensive and active individual participation in the discussion groups is positively related to students' achieved level of knowledge construction, as well as adopting a positive attitude towards the learning environment and towards participating in group discussions. The third hypothesis, however, has to be rejected. No significant differences in levels of knowledge construction were found for students with different learning styles. Students with a deep or strategic learning style did not obtain a significantly higher level of knowledge construction compared to students with a surface approach.

Contrary to the results with regard to student characteristics, the hypothesis regarding the impact of group characteristics were not corroborated. These findings can be explained by the fact that there was very little difference in interaction activity between the discussion groups. This relates to the fact that, based on the previous research results, we changed the 'rules' concerning the minimum participation requirements in the discussion groups. Students were expected to contribute more messages to the discussion groups in order to receive a high evaluation score. As a consequence, hardly significant differences between the groups could be detected as to their level of interaction. Combining of the findings about the impact of both student and group characteristics, makes us aware of the fact that promoting effective group discussion activity is not to be reduced to 'stimulating to contribute a large number of messages'. The fact that also a positive attitude towards the learning environment has a significant and positive impact on student outcomes, stresses the importance of promoting learning as an enjoyable activity (Westrom 2001).

As to the impact of task characteristics, significant differences between the consecutive discussion themes were found. However, the findings were not in line with the expected results. It was hypothesized that students would reach higher levels of knowledge construction when they deal with the consecutive discussion theme assignments. The results showed rather a significant decrease in levels of knowledge construction. Further analysis however illustrated that this significant decrease in level of knowledge construction disappeared when correcting for task complexity. This finding points at the critical importance of the task design and task solution support provisions. Task complexity appeared to be an important task characteristic. When the tasks were too complex, the levels of knowledge construction were significantly lower. On the other hand, when the tasks are too straightforward, students experience no challenge and the number and quality of the contributions also drop.

As to the additional impact of assigning roles, contrary to our expectations, structuring the task by assigning roles to students did not have an additional impact on students' obtained main levels of knowledge construction. These results were not in line with the positive results of role scripting found in other research (Weinberger, 2002; Mäkitalo, Weinberger, Häkkinen, and Fischer, 2004; Jeong & Chi, 1997; Strijbos 2003). But, in comparing our research results, we should take into account that these types of scripting are not completely comparable to the role structuring that was applied in the present study. Moreover, also the dependent variable differs in these studies, which makes it difficult to compare the research results.

Despite the fact that in the present research students' mean level of knowledge construction in the role and no role conditions did not differ, additional analyses revealed some potentially interesting results. As to the differences in the proportion of task versus non-task-oriented messages, no significant differences were observed between the role and no role condition. This is not in line with other research (Strijbos et al., 2004) where students in the role condition contributed more 'task content' focused statements. However we have to put the present findings in perspective by mentioning that an important part of these messages were inherent to the specific role description (e.g., encouraging, planning …).

As stated above, regarding the levels of knowledge construction, the overall picture did not show significant differences. At the end of the semester, the mean levels reached did not differ in both conditions. We noticed however, that the distribution pattern of the levels was no longer similar. In the role condition students more often reached the highest level of knowledge construction, although this was at the expense of messages at level 3 and level 4. There were no significant differences for the proportion of lower level messages. Based on these findings, it can be concluded that even though students' mean level of knowledge construction in both conditions did not differ, the assignment of roles did have an effect on the interaction in the discussion groups. The findings reveal that students in the role condition more often reach the highest levels, but apparently still need a certain amount of low level postings at the start of the discussion activity to ground the rest of the discussion.

Apart from the fact that being part of a role-based group did not have an impact on students' mean levels of knowledge construction, we investigated whether having a specific role assignment had an impact on the levels of knowledge construction for individual students. We found that students who had to perform the role of 'theoretician' did not reach significantly different levels of knowledge construction as compared to students who worked in groups without role structuring. Students who were assigned the role of 'source searcher' and 'moderator', however, scored significantly lower than the reference students in the no roles condition. Only students who had to 'summarize' the discussion obtained significantly higher levels of knowledge construction.

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A New Direction for Log File Analysis in CSCL: Experiences with a Spatio-temporal Metric

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Abstract. This paper discusses the importance and difficulties of assessing interaction between students. To ease the detection of interaction in student groups, a metric is developed that can measure the level of interaction based on log file data. The metric is based on a spatial model and detects actions that take place in close spatial or temporal proximity. After providing a formal definition of the metric, an exploratory analysis of interaction in two different settings is reported to determine the feasibility of the measure: synchronous interaction in a collaborative puzzle game and asynchronous interaction in student groups that use the BSCW shared workspace system.

Keywords: Log file analysis, Spatial models, Interaction awareness, Interaction assessment

INTRODUCTION

Collaborative learning has become a popular approach at most educational levels and increasingly so in higher education (Strijbos, Kirschner, & Martens, 2004). In the past decade most institutions in higher education have implemented Virtual Learning Environments (VLE's) (De Graaff, De Laat, & Scheltinga, 2004). Mostly these systems include a package of standard tools, such as a calendar, document sharing, a discussion forum, and a chat. Essential for such collaborative systems is 'interaction awareness', which help students to maintain an overview of their collaborative processes and provides the teacher a means for assessment.

Most VLE's support interaction awareness through generic notifications (e.g., an indicator signaling new documents) or e-mail digests with recent changes (Chyng, Steinfeld, & Pfaff, 2000). These mechanisms inform students and teachers when artifacts were changed and who made the changes, but they do not provide information about the degree of interactivity within the collaboration (i.e., who responded to whom – or made changes to an artifact - and how close were they related in time). For example, KnowledgeForum© includes an Analytical Tool Kit (ATK) providing descriptive information (e.g., on number of notes written) (Chan & van Aalst, 2004). In technical terms, changes to a calendar, document repository, or discussion forum are considered as manipulations on objects in the environment.

In CSCW research the evaluation of activities is considered as a key factor for improving the design of groupware sytems as it provides an overview of system use. Information about user activities is often recorded by means of log files that include an entry for each interaction of the user with the groupware system (examples have been collected by Pinelle and Gutwin (2000)). Log files usually contain a very large amount of activity data which needs to be transformed to activity reports to compile fine-grained activity data to large-grained indicators for assessment. In CSCL research such activity reports were initially used to assess the extent of collaboration, such as the number of messages (Harasim, 1993), mean number of words (Benbunan-Fich & Hiltz, 1999), thread-length (Hewitt, 2003), and 'social network analysis' (SNA; Lipponen, Rahikainen, Lallimo, & Hakkarianen, 2003). When analyzing log files, it is easy to determine if a user was active, but it is difficult to find out to what extent these activities contributed to the group process. A high level of activity does not imply that the actor is contributing to the group. This is often a wrong assumption read from log files. It is now widely acknowledged that activity reports provide a surface analysis of collaboration at best (Stahl, 2001) and most researchers have turned to in-depth studies of the communicative process (Strijbos, Martens, Prins, & Jochems, in press; Schümmer & Haake, in press).

These in-depth small scale studies are typical for CSCL and provide valuable insights in how knowledge is collaboratively constructed (Stahl, 2004), but they offer little consolation for teachers whose higher education institute has implemented a VLE and are subsequently confronted with large scale supervision and assessment requirements. Students' experiences with various teaching and learning environments are reflected in their study approach and preference (Entwistle & Tait, 1990) and there is growing evidence suggesting that students tune their learning activity to the assessment that is conducted (Scouller, 1997). Thus, if interaction and collaboration are integral parts of the didactical goals but are not assessed, they will not take place to the desired extent. Efficient means for assessing interaction are thus required in a didactical approach that focuses on interaction.

Equipped with activity reports only, temporal and spatial proximity (i.e., changes or addition closely related in time or position in the collaboration space) cannot be detected. Including temporal and spatial parameters can reveal patterns that can support students in their evolving collaboration. Such patterns can assist teachers in making inferences about collaboration efficiency and detect the need to intervene in poorly collaborating groups. Moreover, the generation of activity patterns based on temporal and spatial proximity can provide a better estimate of actual interactivity using log file data. Hence they can be implemented as group and teacher support in those settings where online activities occur on a large scale and where teachers can no longer monitor and supervise all groups in detail. One clue for determining the impact of interactivity can be a measure of success. If the interaction leads to success, it is less likely that the interactive work was not conflicting. However, measuring success is in general very difficult; especially in the case where work or learning concentrates on so-called "wicked problems" (i.e., problems with no fixed or right solution for example 'school dropout') (See Conklin & Weil, 1997).

In HCI research, log files have been widely used and automated tools exist for calculating metric information from the log files in single user applications, which provides clues on how the system is used by the individual user (for an overview on automated evaluation see Ivory & Hearst, 2001). Some metrics like the task completion time or the number of activities per time are easy to adapt and calculate in collaborative applications. An example for a group metric is shown by Begole, Tang, Smith and Yankelovich (2002) who detected the times where a user was actively using the computer and calculated an average activity rhythm chart for specific users or groups of users. This example shows how a single user metric (activities per time) can be transformed into a group metric. But still, the metric does not provide information on the interaction between group members, nor does it reflect that an individuals' work rhythm can be affected by the rhythms of other users.

In general, one can observe a lack in groupware specific metrics that provide clues on groupware-mediated interaction between users. One reason, why groupware specific metrics are rare could be the larger complexity of groupware settings. While one can often clearly define the different usage sequences in single user applications (e.g., the use of a pull-down menu that can invoke a specific action), collaborative applications have to deal with more than one control flow. For instance, discussion boards allow parallel postings of different users or graphical editors allow the concurrent creation of diagram elements. This means that the evaluation of multi-user log data needs to consider the individual users' interaction flows as well as the group interaction, which evolves from the users' actions. In this paper it is argued that such metrics can be calculated and complement analysis techniques known from single user applications. A specific group interaction metric is proposed that measures the degree of interaction in a group, based on temporal and spatial proximity. This metric can be used to extend the expressiveness of group rhythms (e.g., by inferring isolated and interactive parts of group work) for the evaluation of CSCW systems and it can provide clues for supervision and assessment in CSCL environments.

Before the details of the metric are discussed, it is essential to elaborate the difference between system feedback (such as in single user applications) and interaction feedback (in multi-user applications). Next, the mathematical model for the calculation of the proposed group interaction metric is discussed, followed by two examples to illustrate the feasibility of the metric in two distinct groupware systems: a collaborative puzzle game and the shared workspace system BSCW. In the final sections both examples will be contrasted and directions for future applications will be discussed.

A METRIC FOR MEASURING GROUP INTERACTION

The goal of the following analysis is to measure the degree of interaction between the users in a collaborative environment. Interaction between users can be defined as a set of two or more actions that mutually or reciprocally influence one another. In the context of collaborative applications, this means that users modify shared objects and other users adapt their activities according to activities perceived before. Since all interaction is computer-mediated, it can all be reduced to the process of modifying and perceiving shared objects. Close interaction means that users work on the same or on related objects (for example artifacts) at near points in time or in the collaborative space. An object is any information unit shown to the user.

Interaction feedback (IF) relates to three kinds of feedback in VLEs as shown in figure 1. Based on his mental model of the system (*"people form internal, mental models of themselves and of the things with which they are interacting; these models provide predictive and explanatory power for understanding the interaction"* (Gentner & Stevens, 1983)), user A performs object manipulations (1. OM_A). The system answers the manipulation with system feedback (2. SF_A). This can for instance be the update of a visual representation on the screen. At the same time, user B receives activity feedback of user A's activity (3. AF_A). While perceiving the modified object state, B changes his mental model (4. CMM) of the set of shared objects according to OM_A. The changed mental model may trigger an object manipulation of B (5. OM_B). As it was the case for A's object manipulation, OM_B triggers system feedback for B (6. SF_B) and activity feedback for A (7. AF_B). But since AF_B semantically replies to OM_A, it is interpreted as interaction feedback for A (IF_A). This kind of interaction feedback is relevant for detecting group interaction.

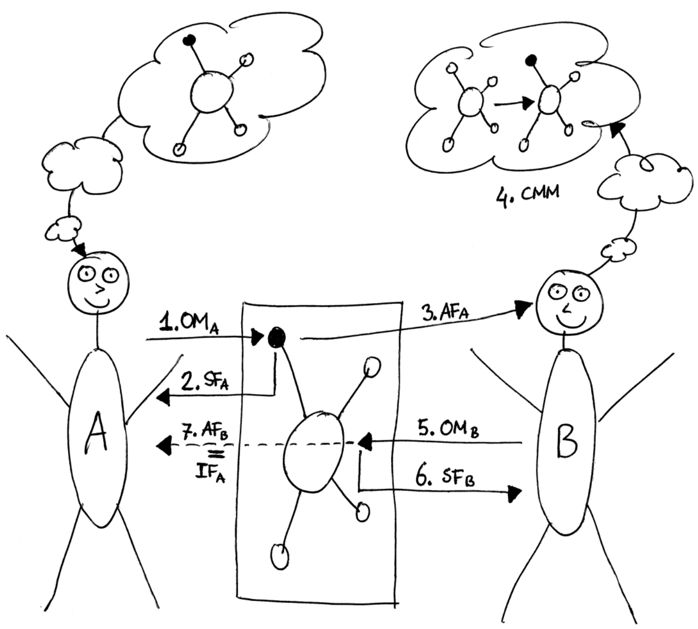

Figure 1: Schematic representation of different classes of feedback.

The difference between system or activity feedback and interaction feedback is similar to that between effects *of* technology (system feedback about manipulations) and effects *with* technology (manipulations as interaction feedback) (Salomon, Perkins, & Globerson, 1991). Naturally, the system generates both types of feedback simultaneously during collaboration, yet system feedback is explicit whereas interaction remains implicit (one could even say 'in the eye of the beholder'). Current activity reports of VLEs focus on system feedback and activity feedback but ignore interaction feedback in their calculations.

Instead of activity reports, group interaction can be calculated (and represented) using a metric based on the spatial awareness model (Rodden, 1996), which has been widely applied in synchronous groupware systems (cf. the *active neighbors* design pattern (Schümmer, 2004) for an in depth discussion of the awareness model and more known uses of and experiences with the model). The spatial awareness model consists of objects, such as artifacts and users, who are distributed in space. Each object has a well-defined distance to all other objects. The distance should reflect the semantic nearness between the two objects. In simple models it can be defined by distances of the objects' locations in a document storage. In this case, one assumes that a user will group related documents in related places of the document storage (e.g., the same folder). A more complex model could analyze the artifacts' content and compare its semantic (cf. Leximancer, a system for creating document spaces (Smith, 2000)). Another approach could be to analyze existing relations between artifacts in case that they are connected by hyperlinks. One example for this approach is provided in (Schümmer, 2002) where items of a web shop are related regarding to their descriptions.

As in the spatial awareness model, the strength of interaction between two activities is defined as the spatial distance of the manipulated objects. In cases, where the system consists of different functional components (e.g., a calendar that manages appointments, a discussion forum that stores contributions, a chat communication channel transferring chat entries, or a shared whiteboard containing graphical objects), it can be appropriate to calculate interaction only for actions on artifacts of the same functional component. Otherwise, a distance function between artifacts of different components is needed. It is assumed that strong interaction occurs when two activities are performed on two artifacts that have a low spatial distance. Besides spatial distances, interaction has to take a temporal dimension into account. It is assumed that two activities occurring at the same point in time – or closely related in time – imply a stronger interaction than two activities that occur at different points in time. Combining spatial and temporal relations of activities surpasses the unrelated information provided in single or multi-user activity reports. In the next section the mathematical calculation of the group interaction metric, termed '**I**nter**A**ction value' (**IA**), will be discussed in more detail.

Calculating the Interaction Value IA

A set of activities $a_1,...,a_n$ is considered as input for the mathematical calculation of the interaction value. Each activity has to provide information on the manipulated artifact, the time $t(a)$ when the activity a occurred, and the user $u(a)$ who performed the activity.

Since the spatial model requires a method for distance calculation between two activities, a function $ds(a_i,a_j)$ is defined that calculates the distance between the artifacts that were the focus of the activities a_i and a_j. In case of a spatial arrangement of the artifacts like in a shared drawing tool, this can be the difference between the positions of the touched diagram elements. In case of structural arrangements like folders in a shared file system, it can be the length of the path between the touched files.

The spatial distance $ds(a_i, a_j)$ has to be combined with the temporal distance $dt(a_i, a_j) = t(a_i) - t(a_j)$ between the two activities. Since space and time are two different dimensions, these are arranged in a two-dimensional vector space. The distance between the activities a_i and a_j can then be calculated as the Euclidean norm of the time distance and the space distance. The interaction $ia(a_i, a_j)$ between two activities a_i and a_j is formalized as

$$\mathrm{ia}(a_i, a_j) = \left| \begin{pmatrix} ndt(a_i, a_j, dt_{max}) \\ nds(a_i, a_j, ds_{max}) \end{pmatrix} \right|$$

with the normalized time distance (*ndt*)

$$ndt(a_i, a_j, dt_{max}) = \max\left\{0, \frac{dt_{max} - dt(a_i, a_j)}{dt_{max}}\right\}$$

and the normalized space distance (*nds*)

$$nds(a_i, a_j, ds_{max}) = \max\left\{0, \frac{ds_{max} - ds(a_i, a_j)}{ds_{max}}\right\}$$

The values dt_{max} and ds_{max} are upper bounds that define which distance activities are considered as relevant. The normalization of the time and space distance by dt_{max} and ds_{max} ensures that the measure for $ia(a_i, a_j)$ can be applied to different types of groupware applications. For example, when analyzing a synchronous groupware application a small value for dt_{max} will be chosen. To calibrate the metric, the values for dt_{max} and ds_{max} have to be found on an experimental basis. Too small values will always result in very small interaction values (a flat line with values close to 0), while too large values will always produce interaction values that are close to an upper bound. An appropriate choice for dt_{max} and ds_{max} will generate interaction values that are distributed between 0 and an upper bound.

It is also important to consider group size in relation to time. As group size increases each group member will have less opportunity to touch or manipulate objects within a given time-span, as users compete for time. This implies that within a large group, there is a higher probability that there will be more inactive people – such as lurkers who are merely following the discussion (in contrast to free-riders who have no intention to compete for time). Logging reading activities includes lurkers as active users who contribute to the group interaction value. Filtering reading activities on the other hand shifts the focus of *ia* to users who collaboratively construct content. Depending on the underlying learning approach – cognitive versus experiential learning as proposed by Rogers and Freiberg (1994) – reading activities can be considered as important or less important. Since experiential learning focuses on the active construction of a solution, modifying activities are central for judging successful group interaction in this case while reading activities can be filtered or rated as less important.

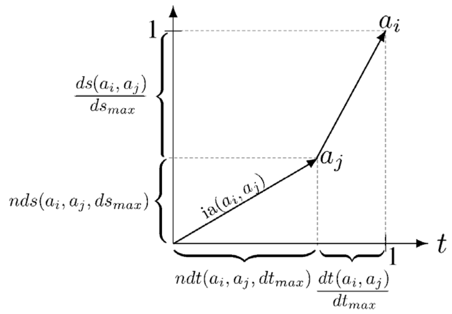

Figure 2: Calculation of the interaction value for two activities a_i and a_j

Figure 2 illustrates that the vector defining the distances between the two activities is subtracted from the vector (dt_{max}, ds_{max}). The result is normalized with respect to (dt_{max}, ds_{max}). Thus, activities that are near in space and time will result in an interaction vector that is close to the unit vector. The interaction value $ia(a_i, a_j)$ is then calculated as the length of the interaction vector.

Up to now, it has been shown how the interaction between two activities can be calculated. The equations can be extended to calculate the interaction of an activity with respect to all previous activities performed by other users within the bounds ds_{max} and dt_{max}. The rationale behind this is that interaction implies that a user reacts to the activities of other users.

For this accumulated interaction value, the sum of all activities' interaction values is calculated for those activities that were performed by other users. In order to calculate the interaction value at any point in time, the time distance calculation *ndt* must be adopted, so that it calculates the time distance between a point in time *t* and the average of the two activities' times $((t(a_i) + t(a_j)) / 2)$. The result is divided by the number *m* of activity pairs (a_i, a_j), which produced an interaction value $ia(a_i, a_j) > 0$. This leads to the following equations for the accumulated interaction value *IA(t)* for a fixed point in time *t*:

$$\mathrm{IA}(t) = \frac{\sum\limits_{\substack{a_i, a_j \in A: \\ t \geq t(a_i) \geq t(a_j) \wedge \\ u(a_i) \neq u(a_j)}} \left| \begin{pmatrix} ndt'(a_i, a_j, t, dt_{max}) \\ nds(a_i, a_j, ds_{max}) \end{pmatrix} \right|}{m}$$

with

$$ndt'(a_i, a_j, t, dt_{max}) = \max \left\{ 0, \frac{dt_{max} - \left(t - \frac{t(a_i) + t(a_j)}{2} \right)}{dt_{max}} \right\}$$

In the next section two examples are discussed that illustrate the calculation of the interaction value, as well as the interpretation of the calculation that can provide clues for students and/or teachers for adapting their collaboration or supervision practices.

TWO CASE STUDIES

The theoretical model was applied to log data from two different applications: a synchronous collaborative learning object (puzzle game) and the BSCW shared workspace system. The next two sections explain these applications and present our findings.

The COAST-Puzzle

A jigsaw puzzle game was chosen for three reasons. First of all, jigsaw puzzles are easy enough to understand for validating the proposed interaction calculation. Users collaborate in a spatial setting and the collaboration strength differs depending on the division of the puzzle space between the users (i.e., users can be active in the same part of the puzzle or work independently in different regions). Secondly, they have their roots in the early 19th century in educational settings (for an overview see Hannas, 1981). Nowadays, jigsaw puzzle games are mainly used in recreational contexts, but depending on the content of the puzzle it can support didactic goals (e.g., a jigsaw puzzle with outlines of countries that have to be assembled to form the European map). Finally, the degree of success (or progress towards the solution) can be measured at any point in time, which allows for comparing the calculated interaction value to the degree of success.

The game has simple rules: a picture of an animal is presented to the user for a short period of time (5 seconds), cut into 30 pieces, and finally scrambled. The players' task is to restore the original image by moving pieces with their mouse. Whenever a user moves a piece, it is moved on the other machines as well. To indicate, who moves the piece, a hand icon is placed on the center of this particular piece. In our example the puzzle was played by student groups of three randomly assigned players. All groups were co-located as shown in Figure 3 and the system stored all moves in a log file.

Figure 3: A group playing the puzzle game.

To apply the interaction value metric, spatial and temporal distances between the activities had to be calculated. The spatial distance was calculated as the minimum of the distances between the two start positions and the two end positions of the activities. Spatial distance was calculated by normalising the positions so that all pieces were squares and thus vertical and horizontal distances had the same impact. The time distance was calculated from the two activities' start times. The values for dt_{max} and ds_{max} were found on an experimental basis. Again, too small values produced too flat curves and too large values produced curves that were constantly at a high level. Finally, *IA(t)* could be calculated for the puzzle logs. Figure 4 shows the result of the *IA(t)* calculation (the thick curve) for which dt_{max} = 21.5 sec and ds_{max} = 3.0, were used, corresponding to the distance of three puzzle pieces.

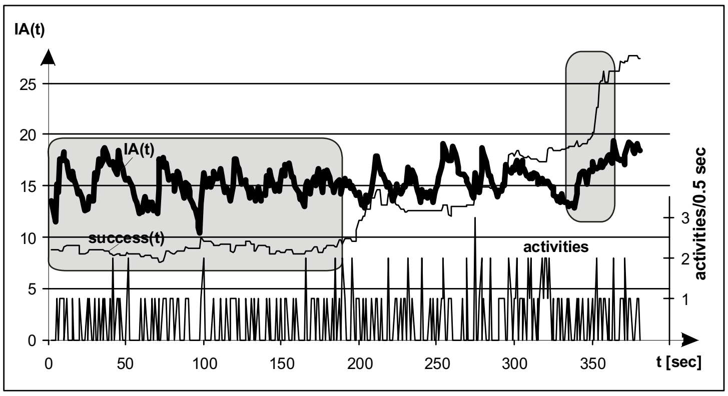

Figure 4: The interaction value *IA(t)* of a puzzle session.

In addition to *IA(t)*, Figure 4 also shows the success of the complete puzzle game as the thin curve. Succes was calculated as the accumulated differences of the pieces current mutual distances to their correct mutual distances. A low value in the success curve thus stands for higher entropy in the puzzle game, while high values represent more order. The third curve (bottom of Figure 4) shows the number of moves per time tick of approximately 0.5 seconds. This example of *IA(t)* reveals important characteristics of the metric that are needed to interpret the graphs. Whenever interaction takes place, the curve rises steeply. If nothing would happen after the interaction, the curve would continuously decline. Any raise in the declining curve indicates that actions relating to the initial pair of interactive actions took place.

By comparing the different curves, conclusions can be drawn regarding the degree of interaction while solving the cooperative puzzle game:

- There are time shifts visible between the curves. This expresses that users sometimes need more time to adapt their mental representation after they percieved another user's activity feedback and perform the required object manipulation. In the right box, this is visible as a peak of interaction, which later on evolves into a strategy of success accompanied by an above-average interaction value.
- A rise in the interaction curve does not imply that the success curve will rise as well. This is visible in the left box in Figure 4 where the interaction curve is variable and the success curve is constant.
- Changes in *IA(t)* provide clues for relevant interactive parts of the log file, which should be examined in more detail. This clue is qualitatively different from clues found in a quantitative analysis of actions per time frame (e.g., activity reports). Even if the size of the time frame is enlarged, the action per time frame curve does not provide sufficient information for detecting interactive sequences in the puzzle.
- The difference between *IA(t)* and the clues drawn from simply counting activities per time becomes clear by comparing the thick curve for *IA(t)* and the thin curve for the number of activities. A large number of activities do not imply a close interaction. Simply counting activities does not consider the relations between different activities.

It can be argued that the cooperative puzzle game represents an artificial interaction situation, hence the interaction value analysis technique was applied to the BSCW environment as this resembles more closely a component of any Virtual Learning Environment: document sharing.

BSCW

BSCW (Basic Support for Cooperative Work) provides folder based workspaces in a tree structure to support cooperative document sharing (Bentley et al., 1997). The main difference to the puzzle game is that users work asynchronously, while in the puzzle synchronous interaction took place. The system has been used in different courses at the FernUniversität in Hagen for several years now.

BSCW log files of a practical training on databases were examined that was held in the winter term 2002/2003. It involved seven groups with six to seven students working for a period of 102 days. Every group had its own workspace and no access to workspaces of other groups to prohibit lurking in foreign workspaces.

To support information exchange across groups, a special discussion workspace was added. Milestones for parts of the project work were defined by the project leaders.

During the course, every access on BSCW objects, such as documents, folders or message boards was logged. The mapping of the BSCW workspace structure to the spatial model of the proposed metric is based on the assumption that users will group semantically related artifacts in the same or related folders in the workspace. A spatial distance can then be calculated as the length of the shortest path between touched artifacts in the folder tree. Temporal distances can be calculated directly from the timestamps of the log entries. The upper bounds for the calculation of the *IA* value were dt_{max}=5.25 days and ds_{max}=3.0. Compared to the puzzle example, dt_{max} was extended to incorporate the asynchronous nature of BSCW. Fig. 5 shows the result for *IA(t)* for two groups *G1* and *G2*. Again, *IA(t)* is shown as a thick line. The second curve shows the number of activities per time sample.

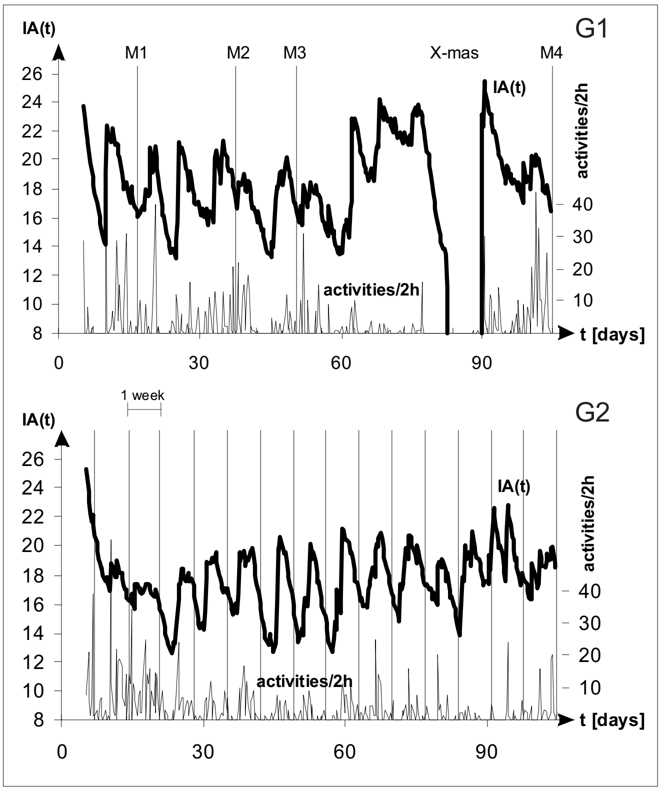

Figure 5: The interaction value *IA(t)* of two groups *G1* and *G2* detected in the BSCW log.

G1 started with a first peak in interaction that was needed to align the goals and create an exposé. This peak corresponds to the maximum before M1 in figure 5. The exposé was the first milestone determined by the teachers. This and three other milestones are shown in the diagram for *G1* as thin vertical lines. After the exposé was done, the group showed a short peak of interaction after the discussion with the course leader. The group had an interaction peak every other week, where they worked on the second milestone (M2: writing a project proposal). The interaction decreased after the proposal was done. In this period of time, the group was asked to refine the proposal and deliver this as M3. The collaboration on this task was postponed until shortly before the deadline. In the final phase, the group had to build a database system based on the project proposal. From the interaction value it can be inferred that the group started to collaborate on the topic about two weeks after M3. Actually, the combination of *IA(t)* with the curves for the number of activities reveals an interesting finding during this time frame: the users started with peaks in the activity curve that had accompanying peaks in the *IA(t)* curve (at a time of 60 days). But in the following days, the numer of activities decreased to a low value while the *IA(t)* value remained high, indicating that users collaborated on very close artifacts. The opposite relation can be observed close to M2. In this part of the diagram, the number of activities was relatively high but at the same time the *IA(t)* value declined. This indicates a situation where users interacted with the system at the same time, but did not relate their activities to activity feedback percieved of other users' activities. In other words, the users divided the task and worked on those parts individually. The first major peak of *IA(t)* after M3 indicates that the group members were realligning their activities.

During the holiday season (Christmas and New Year), the group did not interact at all. This long period of inactivity led to interaction values of 0. After the group started interacting again, the *IA(t)* curve shows a very large peak. This peak does not imply that the group interacted closely. Instead, it is an attribute of the mathematical model: all interaction value curves start with an initial peak since the calculation requires that several user actions can be set into relation. In the interpretation of the diagram, these initial peaks should thus be ignored (or understood as the start-off of group interaction). One last peak can be seen shortly before the final mile stone (M4). From the interaction curve, one can observe that there was no stable group rhythm. Instead, the group interaction peaked before the milestones M2 and M3.

G2 showed a different interaction style that reveals a quite stable group rhythm. Again, the peak in the first week is a result of the mathematic characteristics of the measure (since the measure needs some initial data to tune). The group started with no obvious interaction pattern in the second and third week. The first relevant part of the diagram is at the beginning of the fourth week, where group members worked mainly independent in the BSCW system, which resulted in a decline of *IA(t)*. After the fourth week, the group found its rhythm: they started to have a very regular alternation between interaction and independent work within a period of one week (the vertical lines in figure 5 represent one-week time spans). This rhythm remained stable throughout the course, even in phases with a low activity rate (during the holiday season).

Both interpretations of the log files match with the observations made by the course organizers during chats held at every mile stone.

DISCUSSION

In this paper, a new model for calculating interaction between group members was introduced. In contrast to the 'interaction' provided by activity reports, the alternative model is based on a distinction between three types of feedback resulting from object manipulations by users. Whereas current metrics are based on system and activity feedback, the proposed group interaction metric explicitly incorporates interaction feedback. It thus focusses on object manipulations that are executed in response to activity feedback of other users' actions. By necessity the theoretical model is slightly more extensive than the actual metric being calculated, as it also includes the perception of a change by another participant (awareness) which thrives interaction. Yet, including awareness in the analysis would require far more than log file data.

As shown by two examples, this model can be used to calculate a group interaction metric that incorporates temporal and spatial proximity. Although the puzzle game and the BSCW system have many differences, the same analysis model (defined as a function of temporal and spatial manipulation on objects in the electronic environments) can be applied to detect interaction: Regarding the application of the **I**nter**A**ction value (**IA**) four aspects appear to be relevant:

- **Synchronous versus asynchronous groupware:** This difference is compensated by using different values for dt_{max}. At least in the two cases, it can be seen that an adjustment of the time scale can map synchronous and asynchronous applications to the same analysis method - and the results indicate that interaction can be detected in both cases;
- **Spatial versus workspace structure:** The application of a spatial interaction model in the puzzle game is natural, because the game is based on a spatial order of pieces. In the case of BSCW, this spatial structure does not exist, yet a simple mapping transforms the semantic structure of the workspaces to a spatial structure and makes it available for analysis. For the calculation of relevant spatial distances it is required to compute a baseline for each CSCL context used – as space varies depending on the semantic structure of the educational content and the organization of the artifacts (e.g., a significant difference in space is not the same in a drawing tool as compared to a file sharing system).
- **Success:** In the puzzle, one can calculate the success of the task, whereas this complicated in the BSCW environment since the inherent semantics of the artifacts is more complex. Nevertheless, a calculation of the relative *impact* – based on replies (i.e., whether a contribution evokes a response) – can be included in the mathematical model. The more interaction feedback an activity evokes, the higher is its assumed impact. In this case it is assumed that a higher degree of impact signals that a specific contribution is perceived as more influential by the group members (although this cannot objectively be assessed from log data). Viégas, Wattenberg and Kushal (2004) proposed methods for determining the impact of single user's contributions to co-authored documents. The same methods could be added to the calculations proposed in this paper to better asses the users' activities. Activities with larger impact would then lead to larger peaks in the IA values. Higher average *IA(t)* values do not automatically result in better learning. If interaction is intended in the didactical model, *IA(t)* provides a means to measure whether or not the students complied to this model. Best practices for learning groups can provide a baseline to work towards interpretation guidelines.
- **Group rhythm:** Since the duration of interaction was much longer for the BSCW groups, group interaction rhythms can be observed. In the puzzle game, such a rhythm is less significant although puzzle groups were observed that showed a rhythmic interaction. An analysis of several consecutive games might reveal group interaction for the puzzle game as well.

The examples showed that the interaction value revealed group rhythms in BSCW and the relation between interaction and success in a cooperative puzzle game. The calculation of the interaction value can assist theory building and evaluation to better understand group behavior. The interaction value metric appears especially relevant in those instances where a teacher simultaneously supervises multiple groups and time simply does not allow an in-depth supervision of each group. Although the calculation is based on log files, which are by nature limited in their explanatory power, the proposed interaction value metric extends current metrics that focus on effects *of* the system. It instead it is a metric that approximates interaction between users *with* the system.

It is a simplification to consider all artifacts as generic information objects and rate them all as equally important, as technically the metric could be applied to static educational websites where users are not aware of each other. Whether or not this simplification can be valid in systems that provide different kinds of information objects needs to be determined. Probably, it could make sense to analyze interaction differently according to the different topic areas of artifacts (e.g., having one analysis for calendar entries and another one for pages). It also can be argued that, for example negotiating a meeting (in a nice Irish pub) can 'mislead' the interaction value calculation. Yet, in a learning context social interaction is also important (cf. Schümmer & Haake, in press) and often it is taken for granted in CSCL (Kreijns, Kirschner, & Jochems, 2003). Future research includes the application of the model to discussion groups at the FernUniversität in Hagen to investigate highly interactive courses (in a CSCL-Setting) compared to low interactive courses (within a larger user community) and the difference between moderated and un-moderated discussions and the difference between discussions with long and short discussion threads. Another possible direction is to construct scenarios, such as collaboration patterns of individual members within a group that focuses on the same artifact at the same time, collaboration within subgroups, collaboration within a subgroup and individual work of some other users, and equality of participation in relation to semantically distributed artifacts (e.g., postings in different discussion forums). Finally, the metric could be extended to reveal that users interact differently with group members and a single users' impact on the interaction value, and thus constitute a representation of interactivity that can be generated on demand. Either the group can use this information to coordinate their collaboration or a teacher might use this information to guide specific intervention in a group (e.g., this representation enhances the overall interactivity on the level of group and provides the means to look more closely at the interaction to make a specific decision, for example contacting a less active – possibly free-riding – group member).

Despite the differences between the environments, it has been illustrated that the interaction value can be calculated. This paper has presented first applications of the measure *IA(t)* and the calculated curves revealed promising insights into group interaction. The interaction value can provide information that can be used by groups to coordinate their cooperation or by a teacher to supervise and/or asses the collaboration practice. At present the interpretation of the visualizations requires expert analysis. A tool to assist the application of the metric and automated generation of diagrams for *IA(t)* is currently being developed, which includes generating extreme cases for comparison to aid interpretation of the curves. Yet, further validation of the metric requires a systematic triangulation of log file data, IA value calculation and observations or interviews with students or focus groups. To prove its validity the measure needs to be applied to larger collections of log files (permitting statistical tests). The CSCL community can perform a leading role through applications of the measure.

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Teaching Distributed Software Development with the Project Method

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Abstract. Lab courses are an integral part of higher education in engineering sciences. In this paper, we report about a blended learning approach for such courses in computer science education. We show how the project method for co-located learning can be translated into a blended CSCL setting for a lab course on distributed software development, and how the resulting learning scenario can be supported with the collaborative virtual learning environment CURE. Experiences from the application of the educational approach in two courses indicate benefits but also highlight the need for further technical support.

Keywords: CSCL, project method, blended learning, distributed lab courses, collaborative virtual learning environments, CURE.

INTRODUCTION

In the context of computer science, lab courses on programming are an important part of most degree programs at universities. They foster understanding of programming concepts by actively applying theory in the context of a problem that is comparable to a real-world problem. By situating the learning objectives in a real-world context, the experience becomes more authentic and easier to reuse in later industrial settings. Thus, the learning shifts from knowing *what* has to be done to experiencing *how* problems have to be addressed.

The *Problem-Based Learning* approach (PBL) (Woods, 1994) provides an educational background: Students are encouraged to collaboratively find a solution for a problem. The problem is created by the instructional designer and should be close to reality. PBL has gained major interest especially in engineering faculties (Hadim & Esche, 2002). Addressing practical education in software development with a PBL approach naturally leads to the following structure for collaborative programming labs, which can be often found in practice:

- The teacher announces the lab course together with a description of the task.
- Students register for the lab course.
- Student groups form and norm (Tuckman, 1965).
- Students collaborate following a prescribed problem solving process (i.e. a specific design method such as the Unified Software Development Process (Jacobson, Booch, & Rumbaugh, 1999))
- Students submit deliverables at prescribed milestones.
- The lab course finishes when students have delivered the final milestone and received a grade.

German examples for lab courses run in this way are the eXtreme Programming course at the University of Karlsruhe (Bunse, Feldmann, & Dörr, 2004), the software engineering lab at the Technical University of Darmstadt (Schroeder, Brunner, & Deneke, 1998), or the lab course on databases at the FernUniversität in Hagen (Becking et al., 2004). Similar courses can be found in other countries. In the first two cases, the lab course takes place at a traditional campus-based university. Student groups are able to meet in person and frequently do so. Practices like design meetings or pair programming sessions (Williams & Upchurch, 2001) frequently take place at the University or at student's homes (in the example of Darmstadt). Students have to follow a design method that was described in a lecture before the course. In the the eXtreme Programming lab (in Karlsruhe), tutors closely interact in the process to ensure that the students stick to the roles prescribed by the eXtreme Programming methodology (Beck, 1999). The tutor involvement during pair programming and planning implies that most collaboration takes place at the same place (i.e. a lab at the campus).

An example for a comparable course in a distributed setting is the databases lab. The group process is similar to what is used in the co-located setting, but students interact in a virtual environment (BSCW (Appelt & Mambrey, 1999) and IRC). It is not mandatory that students meet in person at any time during the course.

Again, the process is prescribed by the teachers including information about the required deliverables. All teams have to solve the same task (e.g., design a web-based information system for the university) but have the freedom to distribute work among team members according to group needs. Teachers act as customers and observe the team process. They only intervene if the group is in danger of applying the process incorrectly.

From our experiences at the FernUniversität in Hagen, we see several problems that make the application of the above model difficult in distance teaching programs (such as those offered by the FernUniversität), where students are distributed throughout Germany and other countries, and in most cases have a full-time job that allows only limited time for engaging in the lab course. The problems are:

- motivational problems, e.g. where the students' jobs are more relevant than the lab course,
- schedule problems, e.g. where different courses make it hard to follow yet another prescribed schedule,
- process problems, where traditional processes like the Unified Process are considered as too heavy-weighted for the relatively small task in the lab, and
- communication and interaction problems, where the groups experience difficulties in the group interaction because of deficits in the group building (formation) phase. Weak group building makes it more difficult for group members to understand their peers. This leads us to the opinion that social practices should be learned during a distributed software development lab. These include mastering of distributed teamwork, which we consider as a key qualification in a global environment.

All these problems lead to a high drop-out rate. Due to the fact that the course is based on group work, the drop-out is even more critical since the remaining group members have to restructure their work and often cope with a higher workload after one member left the group.

In this paper, we report on an alternative educational method for distributed labs in the context of software engineering that is based on the project method. We will first provide an overview of the project method and then present our proposal for the application of this method in the context of software engineering education. Then, we show how we implemented the method using the CURE environment (Haake et al., 2004). Finally, we report on our experiences from two instantiations of the course, discuss the experiences with respect to related work, and provide directions for future research.

THE PROJECT METHOD FOR DISTRIBUTED SOFTWARE ENGINEERING

As Knoll (1997) pointed out, the *Project Method* as it is now widely used in Europe has its roots in architecture education in the late 16th century. Nevertheless, the first influential essay on the project method was published by the American educational theorist Kilpatrick (1918) who redefined the term project as a *purposeful act* in the context of child education. The main objective was to allow children to acquire knowledge in practical and social contexts. Though Kilpatrick refers to children, the same applies to the education of adults. According to Kilpatrick, projects should be run in four phases:

- **purposing**, where the student brings in a project idea/goal,
- **planning**, where the the required steps for solving the proposed problem instance are identified,
- **executing**, where the steps are performed, and finally
- **judging**, where the mature student judges the outcome of the process and compares it with his initial project goals.

It is important that all phases should be executed by the students, not the teacher. The teacher provides help where necessary, but the students design the goals and procedures of their process. This is the main difference to the common educational setting outlined in the introduction.

Gudjons (1997) identified eight important characteristics for applying the project method. These characteristics have been refined by many educators and even made their way into recommendations of the Austrian ministry for education (Kölbl, 2001). A project should be

- focusing on the interests of the main participants, namely the students *and* the teacher,
- self-organized by the students in agreement with the teacher,
- following a goal-oriented planning process in the group,
- interdisciplinary with respect to the learning objectives,
- a highly social process that matures social competences of all participants,
- with external effect to the student's environment (which means that the result should be of importance for the participants),
- using cooperative rather than instructional joint activities between teachers and students, and finally,
- activating different senses.

Although these characteristics can be found in isolation also in other educational methods, the project method combines them in a way that is very relevant for collaborative learning. On a theoretical level, the different characteristics of the project method help to overcome the obstacles mentioned in the introduction. Motivational problems are addressed by the purposing phase of the project, which mainly focuses on self defined tasks, goal orientation and the external effect. Schedule problems are tackled by the planning phase of the project method. Since the planning is in the hands of the students, it can be modeled as an iterative activity, meaning the plan can be constantly rescheduled with respect to the group's needs. Process adequacy is approached both in the planning and the execution phase. Students are encouraged to constantly reflect and reshape their work processes and thus learn to improve the process. For reflection, social skills are as necessary as content skills and therefore teachers provide comments on the current process as well as help for students having problems to fill their roles.

For using the project method in a distributed software development lab, we propose the following sequence of actions, which are performed in distributed or co-located settings (as indicated):

Administration (distributed)	
Announcement	Teachers announce the course in the course directory. A supplementary description contains more details on the problem space that can be addressed by the student projects.
Enrollment	Students decide to participate in the course and register for the course providing more details about their background knowledge.
Selection	Teachers select those students that fulfill the knowledge requirements.
Purposing (distributed)	
Project idea generation	Teachers provide the students with a set of requirements that have to be addressed by all proposed projects. These requirements ensure that each project contains all aspects that are part of the learning goals. Students create project outlines for projects that they like to work on. To achieve a larger variety of ideas duplicate ideas are discouraged.
Project idea discussion	Students comment on the ideas generated by other students. The discussion should clarify the individual ideas and provide a shared understanding of possible projects.
Project idea screening	Teachers select the most promising project ideas (since the project should be of relevance for the teacher and for the students, it is important that only ideas are considered for presentation that are in line with the course's goals).
Presentation preparation	The students who created the selected project ideas prepare a short talk advertising their project outline for the first co-located phase.
Group building and Planning (co-located)	
Socializing	An important issue for students who normally do not meet in person is socializing. The students need to get to know one another before they can decide with whom they form a group. Thus, students exchange information concerning personal skills and project preferences. Examples for personal skills are project management or network programming experiences. A good means for socializing can be games although they need to match the social structure of the group (McKee, Solas, & Tillmann, 1998).
Project idea presentation	The students present their ideas in a co-located plenary meeting. After each presentation, there is time for clarifying questions.
Group formation	Students form groups of 5 to 7 people with regard to the information they have of each other concerning personal skills and project preferences. Examples for personal skills are project management or network programming experiences. Students are asked to consider not only the preferences for specific project ideas but also look for a well-balanced distribution of skills within the group. A well-balanced group should at least include one member interested in carrying out the project management.
Project selection	The groups discuss different options for projects and create proposals for their most prominent three projects. The proposals should already include an outline of the intended approach to the project. Teachers then assign projects to groups based on the quality and credibility of the proposals.
Introduction of methodology	Teachers present selected software engineering methodologies. They are intended as an input for the students who are then asked to create their own methodology matching the problem. The methodology addresses problem-specific issues (like programming styles) and social issues (like communication guidelines).
Creation of work plan	The problem is decomposed into small work packages. Students are asked to make first estimates on the required efforts for each work unit. Work units are then put into a workflow.
Assignment of roles	Students assign themselves to roles (identified in the customized group process), areas of expertise, and work units. Each role and area of expertise should be covered by two students to encourage knowledge transfer in the group and to reduce the consequences of drop-outs.

Table 1 (part 1): Phases of the project method.

Execution (distributed)	
Group work	Group members work on small work packages in small subgroups or individually (depending on the possible means for distributed collaboration and the complexity of the task). The students' results are shared and discussed frequently.
Monitoring	Teachers and the project leader monitor the work plan and ensure that the group is aware of any delays in the plan. Group members are asked to recalculate their estimates if the delay increases steadily. The project leader is in charge of monitoring group members' behavior so that they stick to their roles. This does not mean that they may not assist other group members in other roles, but they have to ensure that the responsibilities bound to their role are respected. Teachers only intervene if the project leader does not stick to her role or if the project leader asks the teacher for help. If the group recognizes that specific roles are not well assigned, they can decide to switch the roles (but not frequently).
Inter-group exchange	The groups are also asked to exchange insights regularly. Especially, when different groups have to create software based on the same technology and facing similar issues, this exchange can lead to mutual learning between the groups.
Judgement (co-located)	
Presentation of results	Each group prepares a product presentation. The other groups and the teachers provide ideas for improvement for the groups.
Reflection	Students compare their initial goals with the current state of the project in a project retrospective (Kerth, 2001). They are asked to report on parts of the project work that worked well and parts that failed, e.g. communication or project management issues. The role of the teacher is to point the group to good or bad aspects in their process if the group does not find these aspects on their own.
Grading	Together with the group, the teacher awards a grade based on the insights that students gained.

Table 1 (part 2): Phases of the project method.

SUPPORTING BLENDED LEARNING IN A PRACTICAL LAB COURSE IN CURE

We used the CURE (Collaborative Universal Remote Education) collaborative learning platform to support the above method in distributed software development lab courses. In the next sub section, we introduce the main concepts of CURE. Then, we present how the project method described above is supported in CURE.

CURE in a Nutshell

CURE is based on the metaphor of virtual rooms. Room metaphors (Greenberg & Roseman, 2002; Pfister et al., 1998) have been widely used to structure collaboration. The room metaphor uses the room as the representation of a virtual place for collaboration. Rooms can contain pages (content), communication channels (such as chat, threaded mailbox), and users (see figure 1). Users, who are in the same room at the same time, can communicate by means of a synchronous communication channel (i.e. a chat) that is automatically established between all users in the room. They can also access all pages that are contained in the room. Changes of these pages are visible to all members in the room. The concept of a virtual key is used to express access permissions of the key holder on rooms (such as the rights to enter a room, create sub rooms, edit pages, or to communicate within the room). Rooms with public keys are accessible by all registered users of the system.

Users can enter a room, whereby they can now access the room's communication channels and may participate in collaborative activities. Users can also create and edit pages in the room. Pages may either be directly edited using a simple WIKI-like syntax (Leuf & Cunningham, 2001), or they may contain binary documents or artifacts. In particular, the syntax supports links to other pages, other rooms, external URLs or mail addresses. The server stores all artifacts to support collaborative access. When users leave the room, the content stays there to allow users to come back later and continue their work on the room's pages.

Figure 1 shows a typical room in CURE (the numbers refer to details explained in the following section). It contains documents (in the example, the user Frank reads the document "Homepage" in the room "GoGoGadgeto" – 1) that can be edited by those users, who have sufficient edit rights (2). It provides two room-based communication channels: a mail box (3) and a chat (4). Users can use the room-based e-mail to send a mail to the room. Users of the room (with communication rights) will receive this message.

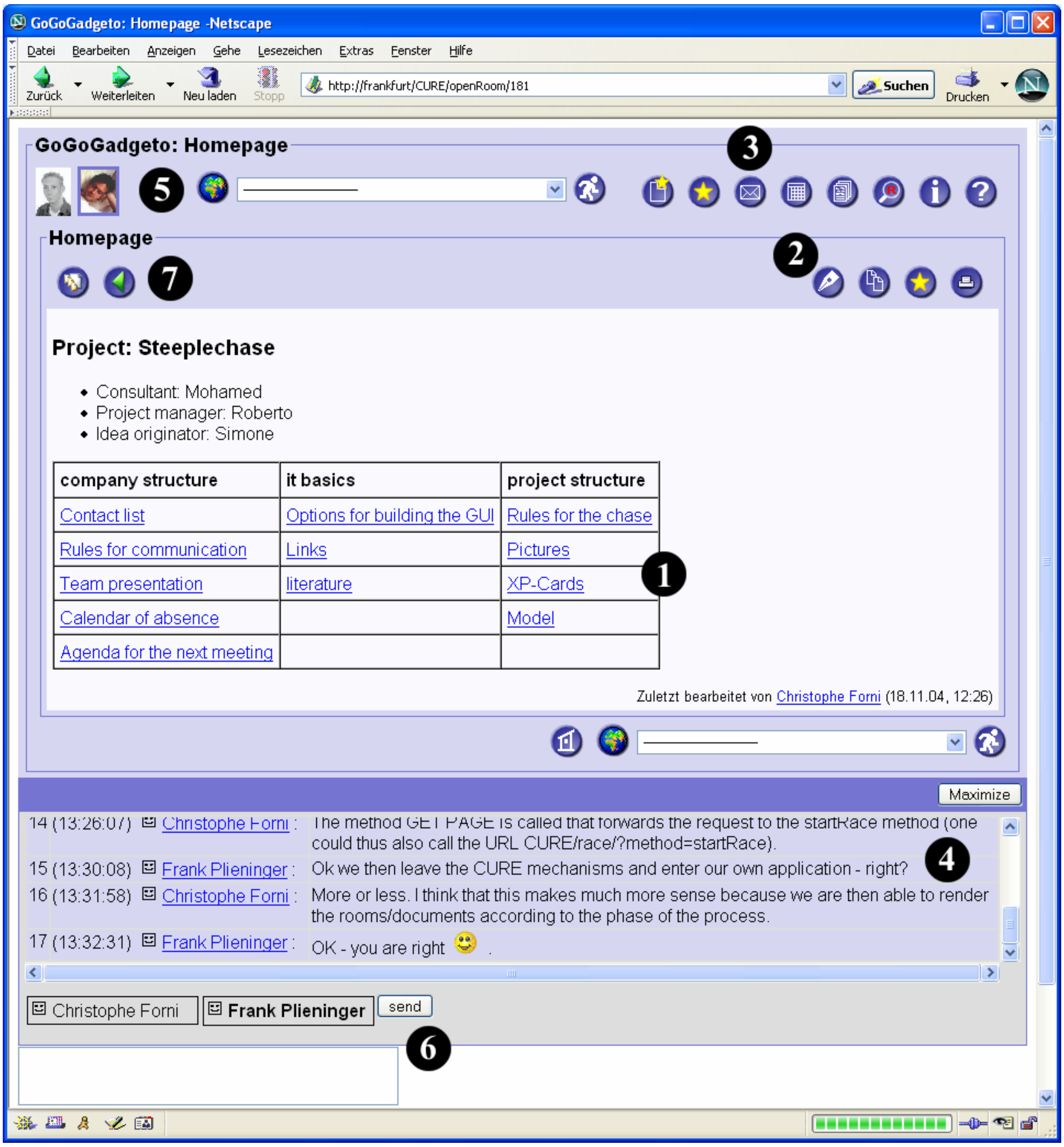

Figure 1: A room in CURE

By providing a plenary room, sharing and communication in a whole class or organization can be supported. By creating new rooms for sub groups and connecting those to the classes' or organization's room, work and collaboration can be flexibly structured. In order to support coordination between the users of a room, different types of awareness information is made available. Firstly, users can see in the room's properties who has access to this room. Secondly, users can see which users are currently in this room (5). Thirdly, if the chat is enabled in the room, they can directly start chatting to each other (6). Fourthly, daily reports automatically posted to all users of a room include all changes made since the last report was sent. If users change pages, the previous state of the page is kept as a version (7) - thus, providing artifact change histories.

To construct structured learning environments, a room may be connected to adjacent rooms, thus forming a virtual learning environment.

Using CURE to support the project method in a distributed lab

In the previous section, we identified several phases for distributed software engineering labs. In the following, we will describe how CURE can be used during these phases. Note that we also show how to use CURE in the co-located phases where we equipped all co-located students with wireless notebooks.

Administration. In CURE, each department of the university can have a public room to organize its courses. For announcing the course, teachers create a new lab room for the lab course. Students are notified by a daily report of the CURE system that a new room, i.e. course, is offered by the department. The daily report contains a link to the new room. By following this link, students can find out more details about the possible problem space for the lab course. Students interested in taking part in the lab course can then enrol in the lab course by requesting a key for the room in CURE and providing information about their previous experience. CURE informs teachers about key requesting students. Depending on the students' background knowledge, teachers can grant students access to the room as long as the maximum number of participants is not exceeded.

Purposing. In the lab room, students find pages with additional information about the lab course. These pages also describe the students' first task and deadline, which is to create a project outline adhering to the basic requirements for the lab course. Students have to create pages in the lab room describing their individual project outline. After the first deadline, students start discussing the proposed projects either by using the mailing list for the lab room or the lab room's chat. Teachers screen the proposed project outlines to select those ideas matching the learning goals of the lab course best. The selected outlines are announced in the lab room so that the respective students can prepare their talk.

Group building & planning. Each user has a personal home page in CURE, which is used to describe the user to other users. Socializing is not proactively supported by CURE. Thus, it is the teachers' task to direct the socializing efforts according to group characteristics. This is done at the beginning of the first co-located phase. Here, students campaign for their project outline and make their presentation available in the lab room for future reference. After the presentations, students have to form groups. For this purpose, students have to create pages in CURE that describe their personal strengths, interests, and areas needing improvement (comparable to the self image game (McKee, Solas, & Tillmann, 1998, p. 26)). Students browse each others' pages and form well-balanced groups around at least one student interested in project management. To ensure that the groups are well-balanced they refer to the previously created personal pages. After the groups were confirmed by the teachers, each group creates a sub room. They distribute keys to all other group members so that the group can from then on collaborate in their group room.

The first group task is that the group members vote on projects that are interesting for them. Based on the resulting project ranking, the groups elaborate project applications for the most interesting projects on respective pages in their group room. They make the pages available for the teachers. Depending on the project applications, the teachers assign one project to each group.

After assigning the projects, teachers introduce the students to possible methodologies and provide additional readings on a designated literature page in the lab room. Each group agrees on one methodology for the execution phase and on the use of CURE as a vehicle for communication and collaboration, e.g. they may agree on reading mails at least every other day or to meet regularly for a group chat. These agreements are documented in their group room. In a next step, the groups begin to create CURE pages specifying required work packages. They link the pages in a logical order on an index page. Additionally, responsibilities and roles are documented in CURE. After this, the first co-located phase ends and distributed work continues.

Execution. Group members sign up for a work package by adding their name to the respective work package page. While performing the work, they use CURE as a work log. The work logs as well as the CURE daily report are used by the teachers and project leader for group monitoring. Teachers and students discuss milestone results via the mailing list of the group room. If the group does not fulfill requirements, teachers intervene and demand a solution. To support inter-group exchange teachers create topic-centered sub rooms of the lab room and require students to discuss topics of common interest in these rooms.

Judgement. In the final co-located phase, each group creates a public sub room for presenting the project outcome. The presented material serves as a basis for discussing the outcome with the other groups in a co-located plenary meeting. Later on, each group reflects about their project using the persistent work logs in CURE and other artifacts like pages, mails, or chat logs. The insights of the reflection phase are stored as pages in the group's room so that students can later recapture the lessons learned. The final phase ends with a collaborative grading of the group.

EXPERIENCES

In order to evaluate whether teachers and students can successfully employ our approach to run distance lab courses, we observed the usage of the system in two instances of a lab course in the computer science program of our university. In the first course, students had to develop a groupware application for collaborative gaming. The second lab course was about tools supporting collaborative learning. We proposed the eXtreme Programming methodology (XP) (Beck, 1999) in both courses. This is a lightweight process model used successfully in co-located courses (cf. the course in Karlsruhe mentioned in the introduction).

Method

Setting. Students were studying from home or office using the Internet and CURE. Both courses used a form of blended learning. Groups would initially collaborate at a distance, and then meet for 3 days (first iteration) or 4 days (second iteration) at our campus, followed by distance collaboration during the term (approx. 4 months), until a final presentation meeting (2 days) at the campus again. During the distributed phases, teachers from our university did communicate with their students via CURE and sporadic phone calls.

Design. We observed the system usage and co-located interaction in the two lab courses.

Subjects. We did not select subjects on a controlled basis. Rather, we deployed our system in existing courses. Students did enrol in these courses as part of their regular studies. Students at our distance learning university are mostly employed elsewhere and thus studying part-time from home or office. In the first course 34 students worked in 6 groups, in the second course 21 students worked in 3 groups. Teachers are regular professors or teaching staff at our university with experience in e-learning over the Internet (e.g. using Mail, Newsgroups, WWW, BSCW, IRC) and expert knowledge about the CURE collaborative learning environment.

Procedure. In the above two courses, teachers were involved in the development of CURE, and thus were already experts in its functionality. Teachers developed their learning environment (a set of rooms and materials) on their own. Then, teachers prompted students to use the system. Students did not receive any training. Rather, they were pointed to the online system manual, which contained a detailed introductive scenario and a reference section. In order to learn from our experiences of the first course, we adapted the approach where needed and observed the implications of these changes in the second course.

Measures and evaluation infrastructure. Due to the distance learning setting, it is difficult to conduct direct observational studies (e.g. taking videos). Instead, we regularly conducted interviews with the teachers present at our university and with some student groups, when they were present at our campus. We also examined the shared rooms and artefacts created by the groups - including their mailboxes and chat logs.

We observed the use of the system with a focus on the four problems listed in the introduction: motivational, schedule, process, and communication and interaction problems. In addition, we looked at the learning outcome with respect to distributed software development and at their achievements in distributed teamwork.

Measures resulting from interviews are reported as anecdotal evidence.

Results

We analyzed the data collected during both lab courses with respect to the following questions:

1. To what degree did students experience **motivational problems**?
2. To what degree did students experience **schedule problems**? How did they solve them?
3. To what degree did students experience **process problems**? How did they solve them?
4. To what degree did students experience **communication and interaction problems**? Did group building help to alleviate the problems?
5. Did students reach the **domain-oriented and social learning goals** of the lab course? Did they show sufficient mastery of distributed software development and teamwork skills?

Course 1: Design of collaborative games

The first lab course followed the proposed outline in most phases, but there were some differences that proved to fail. We will report on these failures since they motivated the genesis of the final sequence of action, as it was applied it in the second iteration. The main differences were in the group building and planning phase:

- The time spent on social games was very low.
- All students were allowed to present their ideas, not just a selection matching the initial requirements.
- Students were allowed to vote for project ideas and the three winning ideas were used as the only basis for group formation.
- Since the co-located phase lasted only three days, a complete work plan was not requested before the group left the co-located phase.
- The role of project leader was not a requirement of the teachers (i.e. groups could organize freely).

These decisions led us into several problems that were our impetus for adapting the educational method to its current form. We will now report the results regarding the five research questions.

Motivational problems: All 34 participating students submitted their personal project proposal. Although each participant was motivated to think about a personal idea, the discussion of other students' ideas during the purposing phase did not take place to the desired extent. Apart from 5 slightly unmotivated students, they presented well motivated presentations of the project. Six ideas were selected and students instantly formed groups for these ideas. They reported that the task was challenging and interesting. Besides one student, there were no free-riders. The problem of this specific student was caused by his deficient background knowledge. Several groups had deficits in major areas required for solving the task. This disencouraged group members in working on the solution. These were the reasons, why group formation was changed in the second iteration.

Schedule problems: All groups reported problems in their schedule concerning the project planning. This seems to be mainly a result of the rather short first co-located phase. The groups started distributed work without having a concrete work plan and clear milestones. Without the concrete work plan, the groups underestimated the required effort and therefore had enormous problems to finish their task in time. In two cases, this was only possible due to the exceptional commitment of single group members. Another group only finished their task by organising co-located development sessions in the final third of the project.

Process problems: All groups were introduced to the eXtreme Programming methodology. Although this is a lean methodology, none of the groups was able to follow all principles of XP. This was partially due to the fact that the groups were distributed and XP has no provisions for distributing critical parts (Schümmer & Schümmer, 2001). But the main reason was that the students had no shared understanding of their tasks and thus failed to play the planning game, a way for identifying customer needs and prioritizing development tasks.

Communication and interaction problems: All groups communicated actively using the mailing list of their room. The total amount of exchanges messages ranges from 205 to 411 in the different groups. The groups with the highest communication load had the strongest commitment to roles and areas of expertise. Especially, the project leader was clearly visible. These groups produced the best results.

Several groups reported on members who were not responding for several weeks. Personal problems resulting in the lack of time were the main reason for this behaviour. These members did not communicate their problems to the group. In one case the problems resulted from a wrongly configured spam filter.

Three groups used a framework for implementing the collaborative game. To introduce these groups in the use of the framework, the teachers created a discussion room, which was used by members of all three groups.

One drop-out was caused by problems in the group structure. The team did agree on the use of a specific technology in the co-located phase. In the distributed execution phase, one group member tried to reverse this decision, which caused a very long discussion. He finally left the group as it would not change the decision. Nevertheless, the discussion caused a lack of trust in the group that was not re-established until the end.

Regardless of the above problems, all group members managed to participate in the group process and contributed to the project solution. Except for the one free-rider mentioned above, no group had difficulties in accepting a common grade for all group members.

Learning goals: All groups produced a working solution to their problem. They reached the desired technical learning goals of the development of distributed collaborative applications. With respect to project organization, the outcome was not satisfying for four of six groups. These four groups did not come up with a convincing project structure. Although often learning was by failure, all groups reported that they learned important lessons for teamwork and software development.

Course 2: Development of tools for collaborative learning

The task in this course was that students should develop tools that assist them in collaborative e-Learning – a task that they are frequently facing in their studies. The resulting tool should be integrated in the CURE environment and foster learning in an entertaining way.

The course had 21 participants. Its structure was changed due to the lessons learned from the first iteration so that it matched the educational method presented in section 2 of this paper. The duration of the first co-located phase was extended to 4 days, and lecture-style parts were tightened, e.g. to a pre-selected number of project ideas that were presented in the plenary, or a shorter introduction to base technologies and methodologies.

Motivational problems: Again, all students prepared a project proposal. The elaborateness of these proposals was in all cases higher than in the case of the first iteration. The ideas were screened and eight ideas that had an appropriate level of difficulty were selected. All screened ideas were rated by the teachers as meaningful supportive means for studies by the participating students. But still, the discussion of other students' ideas during the purposing phase did not take place to the desired extent.

Each group created sound project applications for three of the eight selected project ideas. This reflects that group members could identify with most of the presented ideas. Motivation was thus no longer a problem in the initial phase. In the following planning and execution phases this trend persisted.

Schedule problems: The first iteration showed that students should not be allowed to leave the first co-located phase without a concrete work plan. Although teachers provided less detail on the planning processes used in XP or other software development methodologies, all groups created more concrete plans than in the first iteration. This may be due to a larger focus on demanding work packages in the planning phase. The groups agreed to milestones and documented these in CURE. Wrong calculations of efforts or personal schedule problems led to adaptations of milestones. Nevertheless, the groups always maintained a current project plan.

Process problems: All groups came up with a variant of the XP methodology that was shaped to the distributed nature of the team. A special focus was on the planning game. A result of the planning game was that all groups, compared to the groups in the first course, had a much better understanding of their task and therefore were able to agree on very concrete work plans. The planning cards were managed in CURE.

Communication and interaction problems: The changed way of group formation led to a clear understanding of roles and a responsible project lead in each group. The group members assigned themselves to areas of expertise. The groups frequently reflected about role assignments. For instance, in one case, the project leader changed during the first days after the group noticed that other group members provided a higher competence in moderation and structuring of planning discussions. After two more weeks, the project leadership was split in two parts, a technical and an organizational project leader – since the group discovered that one group member had a very high technical competence. The current role assignment was always documented in the group room in CURE. In another example, the project leader had a severe accident and had to stay in hospital for three weeks. Although he interacted with his group using CURE via the Internet terminal of the hospital, the group compensated his absence by reassigning the tasks. Both examples show that group members were aware of the group's role distribution and adapted their work process during execution.

All groups established communication rules that were documented, presented, and discussed also with other groups. Example rules were as follows:

- *Team members have to read and answer the mails in the CURE room at least every three days.*
- *Vacations have to be communicated within the group room by filling a calendar of absence.*
- *All team members have to meet for a group chat every Friday at 9pm.*

The rules were followed during the course. The communication was more active (with respect to number of exchanged messages and lengths of the chat sessions) than in the first iteration. In one group, the students frequently met in the chat to explain different subject areas to each other. These discussions often had an important social component where team members motivated other team members who had problems understanding technical details. We assume that the more intensive communication is a result of the extended time for socializing and group formation during the first co-located phase.

Learning goals: As in the first course, all groups delivered working results. Additionally, all groups learned more about the process of distributed software development. They acquired social as well as technical practices for computer-mediated distributed project work.

CONCLUSIONS

In this paper, we reported about a blended learning approach that uses the project method in the context of distributed software development lab courses. We showed how the project method can be appropriated to a distributed CSCL setting and how the collaborative virtual learning environment CURE can support this method. From findings of traditional lab courses, we identified several problems when applying the project method in a distributed setting, i.e., motivational, schedule, process, communication and interaction problems. To address these problems, we proposed a combination of the project method with a blended learning setting. In order to evaluate our approach, we conducted two case studies in two distant learning courses at our university. Results suggest that students and teachers can apply the method successfully, that the above problems are reduced, and that not only domain skills (e.g. software development) but also social skills are learned by the students. All groups showed a large level of engagement and did not encounter motivational problems.

Up to now, the project method has been used for fully co-located settings. We are aware of a few settings, where the project method was applied in a fully distributed setting (e.g. by Thomas (2002)). To our knowledge, it was up to now not applied in a blended learning approach (combining distributed and co-located phases). Thus, the proposed modifications of the method, the suggested way of supporting it in a CSCL environment, and the results from two case studies provide new insights into ways for project-oriented CSCL.

In our research we used an iterative approach. During the evaluation of the first version of our approach we still encountered schedule problems. This problem was addressed by extending the first co-located phase in the second course, so that groups now started the distributed work phase with a concrete work plan. In the first lab course we also still encountered process problems. In the second lab course these were addressed by giving groups more time for the planning game so that they left the co-located phase with a much better understanding of their tasks. Since the results of the first lab course suggest that a higher degree of communication in the group leads to better results and that a group needs a mix of students covering all necessary skills to solve the task, we increased the time spent on social games and changed the group formation process. In the second course, students were requested to form groups that are well-balanced according to the available skills rather than based on preferences for project ideas. These modifications of the method proved effective. Although the two iterations provided first insights, future iterations of courses using the project method are needed to show the general applicability of the educational method in a blended learning context.

From a technology perspective, we conclude that CURE seems a good means to support lab courses following the project method. However, despite the use of the same technology (i.e. CURE) the results and encountered problems in both courses differ to a large extent. This emphasizes the role of the social process, which has to complement the technical infrastructure of a CSCL environment. We could observe that problem-centered interaction can be effectively performed in a distributed setting. Socializing and group formation as well as an initial planning of the group process should on the other hand be performed in the co-located phases. Although our second iteration showed to be effective, the ideal balance between co-located and distributed actions is still to be found. Future research is needed to find the optimal fit between social process and technological support.

Besides this question, we are currently experimenting with special groupware tools to support socializing also before the co-located phase. First steps into this direction look promising and we will observe the effects of tools for building up user communities (Schümmer, in press) in future iterations of the lab course.

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Non-linear Dynamical Development of CSCL Communities

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Abstract. The goal of this study was to explore the dynamics of the formation and development of CSCL communities, which is believed to reflect, to a large extent, the interaction among learners. Two different types of CSCL communities (grade four students and teacher education) were investigated. The data representing note reading were analyzed from a non-linear dynamical system perspective. The findings indicate that the grade four data are best described by an exponential model, and the teacher education data by an oscillatory model. We conclude that the method we discuss is potentially useful for understanding the development of reading practices in a CSCL community.

Keywords: Knowledge building, development, non-linear dynamical system

INTRODUCTION

The notion of a learning community has received much attention in recent years, especially in research on CSCL (Brown & Campione, 1990; Lock, 2002; Scardamalia, 2002; Woodruff, 1999). Researchers in CSCL may be interested in how an online learning community develops over time. Factors influencing this development include the task assigned the teachers' interventions. Another question is how the development of the learning community influences individual and collective learning outcomes. Such issues can be investigated empirically. For instance, Hewitt (2003) investigated the development of threads that reflects the interactions among online learners in terms of idea exchange. According to Hewitt, "Online interaction is dynamic and its development is shaped by a wide variety of factors" (p. 32). Those factors include, for instance, the needs and goals of the participants, the requirements of the course the instructor defines (i.e. the invention imposed by the instructor), the role of the instructor, and the emergent properties of the discourse itself (Hewitt, 2003). In other words, the evolution of a learning community is inextricably bound to the setting in which the discussion takes place.

In the case of knowledge building, a specific approach in CSCL, Bereiter (2002) has pointed out the importance of *emergence*. Since nonlinear dynamical models have had some success in explaining emergent phenomena in a number of fields (Guastello, 2002; Morrison, 2002), our research program examines its use for explaining how learning communities—strictly speaking, knowledge building communities—develop. As a first step in this direction, this study examines the trajectories of one variable, *note reading*, in a relatively large set of online discussions in Knowledge Forum™. Follow-up studies will extend the picture we can develop to other variables including variables from social network theory (Haythornthwaite, 2002).

Stahl (2000) posits collaborative knowledge building as a social process of interacting with others, and involving the interplay of group and personal perspectives. Knowledge that can be considered a product of social communication is embedded in the interaction patterns of the communicating societies. In Stahl's study, the learning process is modeled as the mutual constitution of the individual and the social. Knowledge is a socially mediated product.

A CSCL community can be conceived of as a social network in which students are seen as nodes, and the interplays between them occurring in collaborative interactions are treated as social relations (Haythornthwaite, 2002). Social interaction is key to collaboration (Kreijns, Kirschner, & Jochems, 2002). Thus, research on collaborative learning requires exploration of social interactions among learners. According to Vygotsky (1978), social interaction plays a fundamental role in the development of cognition. Within the framework of social constructivism, learning involves peer interaction, including discussion. In other words, learning occurs in a community setting which can be described and analyzed from a social network perspective, which tells us that a community is established through relation(s) linking community members to each other, for instance, reading others' notes in this study.

To study the development of learning communities (and its effect on learning), it is important to understand the nature of learning communities. According to Lock (2002), a community is not only a *product*, but also a dynamic process that evolves with time. As for the nature of learning community, Jonassen, Peck, and Wilson (1999) claimed that learning communities are characterized as a “common cause of mutual support and learning, by shared values and goals” (p. 118). Communication, collaboration, interaction, and participation are four cornerstones for a learning community framework (Lock, 2002). Communication is thought of as pivotal in an online community. Without effective communal communication there is no community (Schwier, 2001). In this sense, researchers with interest in the sustainability of learning communities can analyze the relations linking community members. In other words, the formation and development of a learning community is manifested through revealing the change of a relation or a set of relations that links learners to each other. In CSCL approaches like knowledge building (Bereiter, & Scardamalia, 1996, Bereiter, 2002), the relations among community members are normally established through a series of information and idea exchanges, such as reading and commenting other students’ notes.

Questions regarding the development of learning communities are essentially about the dynamics related to the formation and development of social networks in terms of their size and stability. According to Guastello (2002), communication entails information flows between actors, who are responsible for the development positive and negative feedback channels. This suggests that a non-linear dynamical process underlies the formation and development of learning communities. According to a principle of non-linear dynamical system theory (NDS, Guastello, 2002), the evolution of a non-linear dynamical system is at some stages slow and gradual; the slow and gradual effects culminate into sudden and discontinuous changes of events and conditions. This principle can be used to establish the dynamics of community formation and development, and the conditions under which the non-linear dynamical development of communities unfolds, which will be explored in this study. Dynamics is the study of how variables affect each other over time (van Geert, 1997). Philosophically, dynamic system theory is anti-reductionistic. According to dynamic system theory, the behavior of the system is not influenced in a simply linear way by the factors operating on within it, but is influenced in nonlinear and interdependent ways.

METHOD

Participants and procedures

The participants were students using online discussion in two educational settings. The first database was created by 28 grade four students (approximately ten years old) in a school in metropolitan Vancouver. The school was in an above-average area in terms of socioeconomic status, but the class had a typical range of students in terms of achievement. The students had not used online discussion before but had spent several moths developing an offline learning community. The use of online discussion was integrated closely with other classroom activities as students studied electricity and First Nations issues in British Columbia. The students had access to the database from several computers in the classroom and visited a computer lab two to three times per week. The second database was created by 12 graduate students taking a one-semester course on knowledge building (van Aalst & Chan, 2001). In this case, the online discussion was used to discuss the course’s readings; developing an online community was especially important as the course consisted of two cohorts and the students did not all meet face-to-face. Each cohort met independently on a weekly basis, and the course was also supported by three videoconferences.

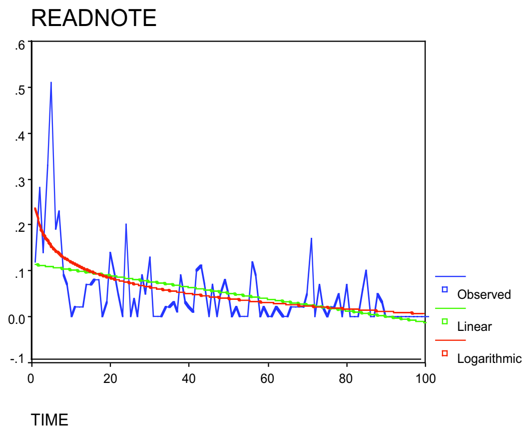
Data and Measures

The two classes used a Knowledge Forum™ (KF) database to record how their collective ideas were developing. KF is a computer-based, communal database that students develop to collaboratively build understanding of certain problems (Bereiter & Scardamalia, 1996). Students’ collaborative contributions can manifest themselves in a variety of activities maintaining collections of notes that represent their understanding of a shared problem. The database can be used to track how individual students and the class as a whole improve understanding, and how understanding progresses. Students write notes; these notes can be read and responded to by others students who have access to the database. In this study we focus on the percentage of notes that have been read per participant. This variable was measured for each day that the databases were active. Note reading is necessary for acquiring information, exchanging ideas, and working to collaboratively improve ideas in CSCL settings. Percentage of notes that have been read per author can, in some sense, be conceived of as the extent to which the class can be expected to be familiar with ideas, information, and theories posted in the database. No online learning is possible with very low amounts of reading each other's notes, as notes record the participants' ideas, information, comments, and so forth. In this sense, percentage of note read by per participant, to a certain degree, represents the extent to which the students engaged in knowledge building activities, although note reading was not the only learning activity in which the students engaged (e.g., they also responded to notes). However, note reading is a prerequisite for other actions.

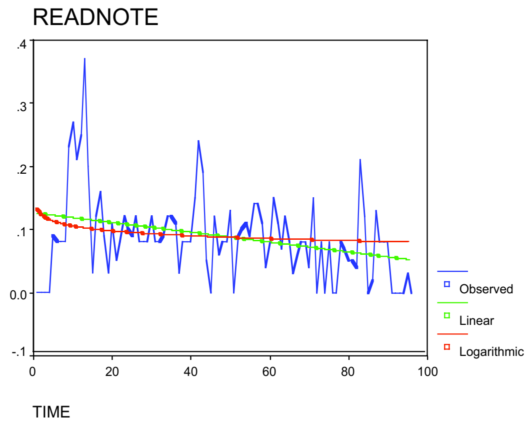
This study aims to preliminarily model the organizational change and development of social networks occurring within a CSCL community from a NDS perspective (Guastello, 2002). Recent dynamical thinking about social networks involves the issues related their formation, development, and stability. In a general sense, the formation and development of networks can be characterized with the growth of the number of links in the network over time. In this study, the quantity of note reading obtained from a software retrieving server-log data from the KF server (the Analytic Toolkit for Knowledge Forum, ATK, see Burtis, 1998*),* will represent this link. A nonlinear regression model with Lyapunov exponent (Guastell, 2002) is introduced to test whether the targeted CSCL communities were undergoing a chaotic expansion positive Lyapunov exponent), were attraction toward a stable state (negative Lyapunov exponent), or were showing oscillating behavior.

Results

All the data from the two example databases were analyzed through curve estimation in SPSS.11. The trajectories of the percentage of notes read in both databases are shown in the figure below.



a) Grade Four



b) Teacher Education

For the grade four data, both linear and non-linear regression models (exponential function models) were calculated to fit the data. The non-linear model provided a better fit to the data than the linear model (R-sq=.37, F=57.39, p=.000 compared with R-sq=.23, F=29.79, p=.000). This means that the dynamics of note reading in this community had a fixed point attractor describing that note reading vanished exponentially. An attractor is a fundamental notion in complex system theory, and refers to states towards which a system may evolve when starting from certain initial conditions (Guastello, 2002). In a general sense, a fixed-point attractor makes a behavior gravitate toward a steady state or a constant value. Other types of attractor include magnetic attractor (fixed-point is a special case of it), chaotic attractor, and periodic or quasi-periodic attractor (Guastello, 2002).

There were three peaks in the teacher education data: near the start, at approximately 40 days, and at approximately after 70 days. From the start to the first peak the percentage of notes grew linearly (R-sq = .31, F=8.2, p=.012); these data could not be fit to an exponential function (p=.10). Between the first and third peaks there were short but quasi-regular oscillations, that is, a limit cycle similar to a sinusoidal wave. Between second and third peaks, there were chaotic oscillations. In this sense, the development of this teacher education database in terms of note reading is essentially is non-linear with a quasi-periodic attractor that is an attractor in non-linear dynamical system holding objects in a limit cycle around the attractor center (Guastello, 2002). The following pedagogical events can help us interpret the three peaks. Approximately 3-4 weeks after the beginning of the course, the class had established standards for participation. Six weeks later, the students wrote portfolio notes stimulating note reading, and they stopped contributing regularly that naturally decreases the activities of reading notes (van Aalst & Chan, 2001).

According to the above brief analyses, it can be concluded that the two sample databases represent two different patterns of community development that should be described using different non-linear dynamical models (fixed-point attractor and quasi-periodic attractor). In any case, a linear model appears not to be sufficient to model the development of note reading in these communities.

DISCUSSION

To date, there are few studies that examine the development of CSCL communities from a non-linear dynamical system perspective. To our knowledge, this study is one of the first attempts to investigate the development of CSCL communities this way. Although this was an exploratory study, it showed that nonlinear modeling described the evolution of reading in these databases better than linear modeling. One of us (the first author) will conduct studies to examine this issue in a large set of databases, and examine knowledge building design, teacher's pedagogical interventions, and student trait variables that may influence the different modes of development of online communities.

This study shows that the reading data are not merely irregular curves, but form a variety of non-linear trajectories. It is hoped that knowledge of critical points and the specific models that describe the data can be used to provide an empirical basis for instructional strategies that can support knowledge building. The non-linear trajectories should not be conceived of sheer irregular curves, but something embracing rich information related to teaching and learning. However, to do that, our analyses must be extended and include more dependent variables (e.g., linkages between notes) and independent variables (e.g., instructional design, the teacher's interventions, and motivation). This study has established a platform on which we will introduce the aforementioned variables and student individual variables to develop more comprehensive accounts of development of effective CSCL communities, linking emergent collective properties of the community to not only its components and their interactions (e.g. students' individual variables), but also to external constraints (e.g. teacher's intervention). The non-linear dynamical feature of the two targeted CSCL communities is emergent; and this means that it cannot be predicted on the onset of collaborative learning. That is to say, philosophically, determinism in principle, but unpredictability in practice underlies the NDS (Carver & Scheier, 1998). It only exists and arises from the interplay of internal factors and external factors. This is a manifestation of micro-to-macro emergence from individual actions (Sawyer, 2001). This goal will be achieved by measuring a substantial number of CSCL communities from which some basic types of non-linear dynamical development would be identified. The revelation of the dynamics of formation and development of CSCL communities will be informative of both CSCL designers and CSCL educators in terms of creating and sustaining CSCL communities.

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Why *All* CSL is CL: Distributed Mind and the Future of Computer Supported Collaborative Learning

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Abstract. In this paper, we argue that this distinction between CSCL and HCI is based on a particular understanding of the relationship between humans and computers—and more generally between humans and their tools in activity systems. We draw on work by Shaffer and Kaput (1999), Clark (2003), and Latour (1996a; 1996b; 1996c) to conduct a thought experiment, extending the analytical reach of *activity theory* (Nardi, 1996b), *mediated action* (Wertsch, 1998) and *distributed cognition* (Pea, 1993) by adopting a stronger form of the concepts of *distribution* and *mediation* in the context of cognitive activity. For rhetorical purposes, we posit this stronger form of the distribution of intelligence across persons and objects as a theory of *distributed mind*. Our purpose in describing a theory of distributed mind as an extension of (but not replacement for) extant sociocultural theories on this 10th anniversary of the International Conference on Computer Supported Collaborative Learning is to problematize for the field its current focus on *human* collaboration as supported by computers. We are concerned that a field focusing on the interactions of humans will overlook the ways in which meaningful cognitive (and therefore pedagogical) activity is distributed among human and non-human agents within activity systems. We argue that *all* computer-supported learning is fundamentally collaborative—whether or not the computer is supporting the interaction of persons in the learning process. The consequences of such a move are a call for a tighter integration of the fields of CSCL and HCI, and a more powerful framework to help guide pedagogical choices in an age marked by rapid expansion of powerful cognitive technologies.

Keywords: Sociocultural theories, activity systems, distributed mind, virtual culture

INTRODUCTION

Over the last decade, work in computer supported collaborative learning (CSCL) has focused predominantly on ways in which computational media make possible new modes of interaction between people in the pursuit of understanding. That is, work on CSCL has focused on how computers support human collaboration. Over roughly the same period of time, work on human computer interaction (HCI) has focused on ways in which people communicate with computers and other computational devices in the pursuit of meaningful goals—including the development of understanding.

In this paper, we argue that this distinction between CSCL and HCI is based on a particular understanding of the relationship between humans and computers—and more generally between humans and their tools in activity systems. We draw on work by Shaffer and Kaput (1999), Clark (2003), and Latour (1996a; 1996b; 1996c) to conduct a thought experiment, extending the analytical reach of *activity theory* (Nardi, 1996b), *mediated action* (Wertsch, 1998) and *distributed cognition* (Pea, 1993) by adopting a stronger form of the concepts of *distribution* and *mediation* in the context of cognitive activity. We suggest that new computational tools problematize the concept of thought within current sociocultural theories by challenging the traditional position of privilege that humans occupy in sociocultural analyses. For rhetorical purposes, we posit this stronger form of the distribution of intelligence across persons and objects as a theory of *distributed mind*.

Our purpose in describing a theory of distributed mind as an extension of (but not replacement for) extant sociocultural theories on this 10th anniversary of the International Conference on Computer Supported Collaborative Learning is to problematize for the field its current focus on *human* collaboration as supported by computers. In an era of increasingly powerful computational games, simulations, and the virtual worlds they create, we are concerned that a field focusing on the interactions of humans will overlook the ways in which meaningful cognitive (and therefore pedagogical) activity is distributed among human and non-human agents within activity systems. We argue that *all* computer-supported learning is fundamentally collaborative—whether or not the computer is supporting the interaction of persons in the learning process.

The consequences of such a move are a call for a tighter integration of the fields of CSCL and HCI, and a more powerful framework to help guide pedagogical choices in an age marked by rapid expansion of powerful cognitive technologies.

BACKGROUND

The dilemma of action

To illustrate the issue at hand, we begin with a contradiction. In *Mind As Action*, Wertsch (1998) offers a historical review of research on human action, describing a moment in Kenneth Burke's theorizing when Burke contrasts the actions of persons with the "sheer 'motions' of 'things'" (p. 12). Burke claims that he is "not pronouncing on the metaphysics of this controversy," for "the distinction between things moving and persons acting is but an illusion." However, Burke adds: "Illusion or not, the human race cannot possibly get along with itself on the basis of any other intuition" (p. 13). For Burke, humans need to remain at the center of activity because it is too disconcerting to think otherwise.

Computation media problematize this basic intuition because modern computers—and equipment controlled by computers—act independently in ways that traditional tools do not. Thought and action are no longer the sole property of humans: computers and other digital tools exhibit significant kinds of thinking and important forms of independent activity. They create a variety of situations in which people clearly think *with* rather than *using* tools.

In what follows, we argue that although existing sociocultural theories of cognition assign an essential role to objects in their frameworks for studying action, in a sense, Burke's center still holds. Computational media thus provide both a means and a motive to push beyond current theory. We ground this claim about the significance of computational media in understanding thought using the theory of *virtual culture*.

The evolution of virtual culture

A number of theorists, including Dewey (1991), Clark (2003), and Bateson (1972) have written about the co-evolution of tools, culture and cognition through which, as Donald (1991) suggests, "the individual mind has long since ceased to be definable in any meaningful way within its confining biological membrane" (p. 359). Building on a large body of prior work on the development of writing (Schmandt-Besserat, 1978, 1992, 1994), Donald argues that with the development of extended societies within a mythic culture, the record-keeping needs of commerce and astronomy led to the creation of external symbol systems, of which mathematical notations were probably the first (see also Kaput & Roschelle, 1998). Donald suggests that these external records led to the development a *theoretic culture* based on written symbols and paradigmatic thought characteristic of scientific disciplines. DiSessa (2000) describes historically powerful representational and inscriptional tools such as writing and mathematical notation as *infrastructural*. In a theoretic culture, such tools play a leading role in cognitive activity and thus in formal education. Schooling in a theoretic culture focuses on learning to access parts of the cultural record and manipulate them through writing and mathematical notation (Donald, 1991).

Writing and mathematical notations are, of course, static representational systems, and therefore thinking in a theoretic culture can be reasonably characterized as the result of human agency mediated by cultural tools. Computational media, however, are inherently dynamic representations (Kaput, 1986, 1992, 1996a, 1996b; Kaput & Shaffer, 2002; Papert, 1993, 1996; Shaffer & Kaput, 1999), and thus suggest a different relationship between tool and person. Building on Donald's framework, Shaffer and Kaput (1999) describe computational media as a new transformative tool, one in the process of creating a new cognitive culture. They argue that just as theoretic inscription systems such as writing and mathematical notation externalize human memory, computational media make it possible to externalize well-formed algorithms. That is, computers make it possible to create artifacts that take a particular form of thinking (understanding that can be expressed in the form of a finite state algorithm) and allow it to be carried out independent of any person. Computation thus makes it possible to develop simulations that dynamically enact and reenact parts of the way we understand our world. Shaffer and Kaput argue that if written symbols led to a theoretic culture based on external symbolic storage, then computational media are in the process of creating a virtual culture based on the externalization of symbolic processing.

Theories of Mediational Means, Activity Theory, and Distributed Cognition

A broad range of recent work in psychology and anthropology supports the basic contention that the relationships among thought, action, and technology are essential in understanding learning. This body of work examines the problems with analyzing thought and action from the perspective of an individual without taking into account the context of tools and social interactions in which thinking and acting take place. In addressing this concern with context, theories of mediation means, activity theory, and distributed cognition in particular have attempted to grapple with the role of technology in thinking:

Each of these theories begins by positing that activity necessarily takes place in the context of mediating tools. Wertsch (1998), argues that thinking always emerges through action with mediational means—that is, with tools—and thus learning is not the acquisition of isolated skills that transfer to from one context to another, but rather the *mastery and appropriation of cultural tools*. In activity theory, this premise is represented by Vygotsky's (1978) model of mediated action, which relates subject, object, and mediating artifact (Engestrom, 1999). In distributed cognition, Norman (1993) describes a similar framework for analysis as an equation, with the system of activity composed of a person and an artifact. There are important distinctions in how these theories frame the issue. But they all suggest that the appropriate unit of analysis for thought and action is the interaction of people and tools in social context, rather than the level of either persons or tools in isolation.

One important issue these theories address is the relationship between artifact and person within this unit of analysis. Activity theory proposes explicit linkages among individual actors, tools, confederates, and the norms of action within a social context (Engestrom, 1999). In so doing, it provides a descriptive framework for clarifying the unity of consciousness and activity by positing that consciousness is located in practice, which is, in turn, embedded in an historically-developed social matrix of people and artifacts. Distributed cognition similarly proposes that knowledge resides in people, in tools, and in cultural settings in which people interact with tools without being locatable exclusively in the heads of individual persons or in the design of specific artifacts; that is, the parts of the system have knowledge, but the system as a whole is more knowledgeable than the sum of its parts (Hutchins, 1995). Distributed cognition analyzes the persistence of knowledge in such systems, both in the form of physical artifacts and in the processes through which the system perpetuates its norms and functions (Nardi, 1996a).

However, all of these theories posit an asymmetrical relationship between persons and artifacts. This distinction is explicit in the case of activity theory, which identifies three levels of means as *operation*, *action,* and *activity,* with the corresponding ends of *instrumental conditions, goal*, and *motive* (Engestrom, 1999). The later (motive) is ascribed only to human beings (Kaptelinin, 1996; Nardi, 1996a), and thus the structure of the highest level in the operation/action/activity framework is by definition determined by the human agents in the system. In distributed cognition, the asymmetry is less explicitly drawn. Both humans and artifacts are referred to as *agents* in the system. However, theorists of distributed cognition such as Solomon, Perkins, and Globerson (1991) make the distinction between the things a person can achieve *with* a tool, and the effects *of* that tool on his or her thinking in other contexts—that is, without the tool. While Pea (1993) rejects this formulation, he does assert that "the primary sense of distributed intelligence arises from thinking of people in action," and adds in a footnote, "I take the work of Leont'ev on activity theory as arguing forcibly for the centrality of people-in-action, activity systems, as units of analysis for deepening our understanding of thinking" (p. 49). And elsewhere: "I use the phrase 'distributed intelligence' rather than 'distributed cognition,' because people, not designed objects, 'do' cognition" (p.50). Wertsch's conception of the relationship of persons to objects is implied in his construal of mediated action as meaning "agent-acting-with-mediational-means." Wertsch (1998) explains, for example, that "the task of a sociocultural approach is to explicate the relationships between human action, on one hand, and the cultural, institutional, and historical contexts in which this action occurs, on the other" (p. 24). From the standpoint of these frameworks, activity systems are something to be analyzed by focusing on human action. Each thus reinscribes Burke's center: it is people who are do the acting.

The problem this poses from the point of view of virtual culture is that when we use the general category of human action to analyze activity, focusing on the person using the tool obscures the active role tools play. This may not have posed a significant problem in analyzing the static inscriptional systems of a theoretic culture. But in a virtual culture based on the offloading of symbolic processing, we may need to end—or at least reconceptualize—the analytic privilege we accord humans in the process of thinking and acting. In the next section we describe work by Latour as a basis for orienting to objects and humans as more genuinely equivalent participants in activity systems—and thus, by extension, in cognitive activity.

Latour's translation model of action

Latour (1996b; 2000) describes how objects, by virtue of their being in the world in some form (physical artifacts in the physical world and informational artifacts which are represented in speech, text, or in action on a computer screen) *push back* in their interactions with humans. A thought, once instantiated in an object, is no longer exactly that thought, for it now has an independent existence in the world. It is a *something* situated in the world. We can *fold ourselves into* an object, but the object always expresses our thoughts, values, intentions, and norms with its own "timings, tempos, and properties" (1996a, p. 268)—that is, in its own particular form. Latour gives the example of delegating to a wooden fence the task of containing sheep. He asks, "Are the sheep interacting with me with when they bump their muzzles against the rough pine planks?" And answers, "Yes, but they are interacting with a me that is, thanks to the fence, disengaged, delegated, translated, and multiplied. There is indeed a complete actor who is henceforth added to the social world of sheep, although it is one which has characteristics totally different from those of [human] bodies" (1996a, p. 239). The fence enacts Latour's intention to keep the sheep all together in one place to make sure that none wander off. His action is folded into the nature of the fence; but if one looks for a "mind" in this situation, it is as much in the head of Latour, who is now freed up to read a book, as it is in the fence that enacts a particular way of thinking (keep the sheep together), a way of valuing (although they might not like it much, it is more important for sheep to be penned up than for them to roam free), and a way of interacting (now the sheep interact with the fence rather than with Latour). The relation between humans and technology is thus best conceived not as humans *using* objects, but rather as humans *interacting with and through* objects.

From this perspective, action has no point of origin; rather action is a moment of translation in which *actants* (things and people) come together to share in action, which is mutually distributed between them. Latour argues that "to act is to mediate another's action" (1996a, p. 237). Both humans and objects mediate, and one can only proceed to action by mediating another's action. As a result, this conception of action does not grant analytic priority to humans, since action is a moment of mutual mediation between actants, "no one of which," Latour explains, "ever, is exactly the cause or the consequence of its associates" (1996a, p. 237). In developing the concept of distributed mind, we take as a premise for our thought experiment that persons and artifacts are equivalent actants in this sense: persons and artifacts engage in mutual mediation, and the actions that result are not ascribable more to one than the other.

FROM TOOLS AND THOUGHTS TO TOOLFORTHOUGHTS

A virtual cognitive ontology

Latour's model of action reorganizes our thinking about cognition by challenging the idea that humans have a privileged position in action. Seeing action as an association of multiple mediating actants pushes us out of the western anthropological schema which, Latour (1996a) suggests, "always forces the recognition of a subject and an object, a competence and a performance, a potentiality and an actuality" (p. 237). If objects were only the reified intents or concretized designs of their makers, it would make sense to orient to them, as Pea (1993) suggests, as things that *have intelligence* but cannot *do cognition*. The structuring effects of objects designed to shape action (and thus also thought) would be principally relevant to our understandings of activity. Yet, as is often noted, objects have a way of exceeding or changing the designs of their makers (Postman, 1993; Tenner, 1997). To the extent that a tool *expresses* desires, intentions, and meanings, the desires, intentions, and meanings that the tool enacts are never precisely those of any single individual. A tool has its own characteristics and properties that shape action in ways that are influenced by, but not reducible to, the initial inputs of its designers and users.

Instead, we suggest that just as tools are externalizations of human designs, thoughts are similarly internalizations of our actions with tools—both physical tools, such as Latour's fence, cultural tools, such as language, and social tools, such as the system of property rights that makes it possible to Latour to erect a fence on "his" land around "his" sheep. All thoughts are connected to tools, and all tools are connected to thoughts: every time we consider a thought (since it is an internalization of action with a tool) it is inextricably linked to a tool, and every time we consider a tool (since it is an externalization of a thought) it is inextricably connected with a thought. In this view, tools are not distinct from thoughts; rather, both are poles in the back and forth movement between tool and thought. The reciprocal relation between tool and thought exists in both. We thus suggest that rather than seeing tools as static thoughts—objects distinct from human subjects—we grant tools and thoughts the same ontological status. That is, we posit that tools and thoughts are fundamentally the same kind of thing. Put another way, the concept of persons and objects as equivalent actants removes Vygotsky's (1978) distinction between *sign* and *tool*. Vygotsky argues that both are mediators of activity, but since signs orient internally and tools orient externally, "the nature of the means they use cannot be the same" (p. 55). Positing symmetry between persons and artifacts argues that all activity is simultaneously internal and external, and that the processes involved are therefore not ontologically distinct—different in specific properties, perhaps, but not in their fundamental nature.

Toolforthoughts defined

In this ontology, then, there are no tools without thinking, and there is no thinking without tools. There are only *toolforthoughts*, which represent the reciprocal relation between tools and thoughts that exists in both. When we say that something is a *tool for thought* (as separate words) this might suggest that *thought* is the broader category and that tools are something that help people think. Or it might imply that *tool* is the broader framework and persons are agents who use both thoughts and physical artifacts as tools. To avoid these difficulties, we connect the nouns *tool* and *thought* in order to suggest how toolforthoughts are the outcome of a process of tools existing in a reciprocal relation with thoughts.

Whether they are internalizations of social interaction (Vygotsky, 1978), or externalizations of cognitive processes (Shaffer & Kaput, 1999), toolforthoughts are templates for action: reifications of patterns of social action that arise from an ongoing historical dialectic between tool and thought.. We refer to these reifications as templates because they have a particularity to their form. This particularity does not ensure that toolforthoughts enact the social organizations that their inventers intend—a toolforthought is a social pattern, and no one would expect that intent is equivalent to outcome in a social setting. The particularity of a toolforthought does imply, however, that when a toolforthought participates in action, the action is inflected by the pattern of the template: some actions, while perhaps still possible, are less likely to emerge than others; other actions, while perhaps not inevitable, are more likely to emerge. Toolforthoughts collaborate in some ways better than other ways, creating a set of constraints and affordances for any toolforthought (Gibson, 1986; Norman, 1993). Any action that unfolds with a toolforthought unfolds in some particular way, rather than in another way; thus all toolforthoughts are inherently ideological. As Postman (1993) argued, every tool implies "a predisposition to construct the world as one thing rather than the other, to value one thing over another" (p. 13).

Toolforthoughts as objects of study

As understood in the context of theoretic culture, tools and thoughts divide the space of mediation and activity: as an artifact, a tool mediates but does not act; as an agent, a person has thoughts, but does not mediate. The construct of toolforthought, in contrast, preserves the unity of action and mediation. Toolforthoughts are the cognitive instantiation of Latour's mutually mediating mediators. Toolforthoughts neither act nor are acted upon; rather, they interact to produce a model of thinking that goes beyond current conceptions of mediated action, activity systems, and distributions of intelligence or cognition. In this model, biological cognition itself is a form of mediation, with the same ontological status as that of other mediators, and thinking, in the words of Latour (1996c), involves "constantly shifting from one medium to the other," with work divided between "actors in the setting, either humans or non-humans" (p. 57).

We refer to this as a theory of *distributed mind*, and we suggest that while extant theories, such as actor network theory, activity theory, and theories of mediational means and distributed cognition contain elements of this theoretical stance, a theory of distributed mind is distinct in its explicit emphasis on the ontological equivalence of tools and thoughts—and their linkage in the concept of toolforthought as the fundamental unit of analysis for cognition. In such a framework, the appropriate unit of analysis is not a system *comprised* of human beings and tools, but rather *systemic effects of individual toolforthoughts* and the particular forms of social interaction they foster. For each toolforthought, the task is to understand its particular constraints and affordances—and to uncover how the linkages between the two participate in particular kinds of social interactions at the expense of others.

EXAMPLES

Toolforthoughts in mathematics

Not long ago, solving many mathematical problems necessarily meant representing them in algebraic notation and solving a system of equations. For example, the motion of a ball after it is thrown was determined by representing the motion with equations $x_t = x_0 + v_{xo}t$ and $y_t = y_0 + v_{yo}t - ½gt^2$. The same problem can now be solved with a variety of new quantitative modeling toolforthoughts. Papert, for example describes how even very young students can use a similar process to solve complex problems of projectile motion by creating a simulation in a LOGO microworld (Papert, 1980). Such methods provide a range of techniques for solving interesting and important problems that cannot be addressed in the traditional mathematics curriculum.

The point that new tools open new avenues for solving problems has been made many times before (see, for example, Kaput, 1986; 1992; Papert, 1980, 1993, 1996; Resnick, 1991, 1994a, 1994b; Shaffer & Kaput, 1999; Shaffer & Resnick, 1999). However, the concept of toolforthoughts changes our understanding of the implications of this expansion. One might defend the primacy of algebra in the curriculum by arguing that only when using algebra are students really *doing*, and thus really *understanding*, mathematics; it is the spreadsheet, or modeling environment that is solving the problem when a student uses a computer. But this argument is only sustainable when cognition is taken to be a certain kind of action that can only take place in certain kinds of activities—in this case something happening in the head that is only manifest in symbolic manipulation. If we define mathematics as computation using particular techniques then, indeed, when these become externalized in a new tool, the original endpoint of instruction has been taken over by the tool.

The theory of distributed mind, however, focuses on the outcomes of interacting toolforthoughts. It emphasizes how new tools lead to new kinds of actions, and thus to new modes of thought. In this view, the reason for introducing new technologies into the classroom is not to recreate existing activities, but rather to allow more compelling possibilities that new toolforthoughts provide. Because there are no thoughts independent of tools (or tools devoid of thought), intelligence is always the collaboration of toolforthoughts. Pedagogy *does* sacrifice understanding is when a toolforthought is being used to do the thinking (a type of action) that is already folded into it. However, the understanding being sacrificed is not *what has been folded into the toolforthought*. That understanding is still present but has been relocated. The understanding being sacrificed is the understanding that comes from *actions that are only possible with the aid of the toolforthought*. Using a calculator to add 2+2, does not sacrifice the ability to add. That capacity is still present in the person-calculator system. What is sacrificed is the understanding that would come from working with the calculator to do something we cannot do with pencil and paper alone.

In other words, it is not new toolforthoughts that potentially diminish understanding, but rather curricula—or, more precisely, a poor match between toolforthought and activity. Thus, Pea's (1993) suggestion that we have to balance between "deeper understanding" and "engaging in meaningful whole-task problem solving" (p. 74) is a dilemma that only arises from a particular way of thinking about technology, cognition, and learning. In the theory of distributed mind, all thinking is a tool-thought combination. Understanding mathematics does not depend on mastering traditional mathematical toolforthoughts. It means being able to interact with a suite of powerful toolforthoughts to accomplish meaningful mathematical ends.

From this perspective, algebra is not inherently more powerful than other mathematical modeling systems, other than the power it has by virtue of its place in the historical development of mathematics. It may be more powerful. But now that case needs to be made through an analysis of its constraints and affordances, and their resulting social consequences. It is not enough that algebra has traditionally been a dominant toolforthought, because algebra has also traditionally disempowered a wide range of students—and many important problems are beyond the scope of traditional algebraic techniques. New toolforthoughts potentially let more students work with complex mathematical relationships than the mathematics curriculum of theoretic culture (Kaput & Shaffer, 2002; Papert, 1980). These new possibilities for mathematical understanding depend not on mastery of the traditional forms of theoretic culture, but rather on learning to collaborate with a system of mathematical toolforthoughts to achieve meaningful ends.

Toolforthoughts in literacy

Bolter (1991) describes a *writing space* as the interplay of writing materials and techniques of inscription used to produce literacy objects. Not surprisingly, paper is the dominant writing material in a theoretic culture, and symbolic text is the dominant technique of inscription. Theoretic writing spaces thus emphasize print literacy, and theoretic schooling emphasizes the production and consumption of symbolic text as a primary literacy activity. That is, school focuses on learning to read and write words on paper.

Writing in a virtual culture, however, increasingly means collaborating with a range of toolforthoughts: artifacts that represent new and expanded access to traditional forms of writing (the Web), but also modes of communication that were not previously available (interactive multimedia), or were available but not in the form of writing technologies (immersive role playing simulations). Forms of representation that are not considered writing in a theoretic culture—for example, movement through space and situational gestures that are all but unwritable in pen and ink—are critical elements of writing in virtual media such as videogames.

The basic cognitive engine of virtual culture is the externalization of symbolic processing: the instantiation of dynamic transformations in new toolforthoughts. These externalizations in virtual worlds make it possible to extend and recombine physical forces and responses such as gravity, agility, and location, to create new ways of being in the world. In videogames and other computational spaces, we "read" concepts in more experiential (Norman, 1993), more embodied ways (Gee, 2003). This experiential aspect of virtual writing spaces makes possible new ways of knowing and new modes of understanding. In a theoretic culture it is possible to conceive of literacy as an interaction between tool and person: between the text and the reader or writer. However, new forms of reading and writing such as we find in videogames and other simulations require a degree of projection (or inhabitance) that makes it increasingly difficult to analytically separate person from tool. Indeed, what is the ubiquitous avatar if not a representation of the tight coupling between computationally literate person and computational literacy object?

The potential consequences of this increased embodiment are profound. In theoretic culture, writing is used to create a *world on paper* (Olson, 1994). Understanding a world on paper requires experience of the real-world contexts to which the text refers (Glenberg, Gutierrez, Levin, Japuntich, & Kaschak, in press). In virtual culture, writing both creates a *world on the computer* and provides the experiences needed to understand that world. In video games and other computational spaces, we have the potential to dwell in the virtual world through a new form of direct experience. As a result, the lengthy cognitive apprenticeship in the dominant symbolic systems of theoretic culture are no longer required to have meaningful experiences in complex cognitive domains. Papert (1980) famously suggested that computers make it possible to learn mathematics by living in Mathland as one can learn French by moving to France. Similarly, more people can learn French by playing a massively multiplayer online computer game conducted in French. Learning in digital worlds means developing an understanding of the world from the inside, for it is through one's own action in digital worlds that they take on meaning. In other words, virtual literacy makes existing forms more widely accessible at the same time it gives us access to new worlds—social, conceptual, and material.

Digital worlds thus support a view of learning which foregrounds having particular kinds of experiences and accomplishing meaningful ends. We evaluate toolforthoughts in virtual literacy by the interactive, communicative, interpretive, and expressive ends that students can accomplish in collaboration with them. Think, for a moment, of students who come to know Hamlet through multimedia projects (Murray, 1999)—or some day perhaps through a Prince of Denmark video game. These students may not be facile at translating words reprinted from Shakespeare's Folio or Quarto into a personally-relevant interpretation of the dilemmas that face the troubled prince. But that was, after all, not Shakespeare's intent in writing the play. Hamlet was written to be seen, not read. More to the point: from experiencing the play through a range of literacy toolforthoughts, more students will be able to interact with the themes of Hamlet, the nuances of Shakespeare's dramatic skill, and the relationship between performance and interpretation that the play represents.

Video games as toolforthoughts

We close this section with a specific example that exemplifies the power of new toolforthoughts as interactive learning environments, and the challenges they propose to traditional notions of CSCL. *Full Spectrum Warrior* (Pandemic Studios, for PC and Xbox) is a video game based on a U.S. Army training simulation. But *Full Spectrum Warrior* is not a mere first-person shooter in which the player blows up everything on the screen. To survive and win the game, the player has to learn to think and act like a modern professional soldier. (For a more detailed discussion of the game, see Gee, in press.)

In Full Spectrum Warrior, the player uses the buttons on the controller to give orders to two squads of soldiers, as well as to consult a GPS device, radio for support, and communicate with rear area commanders. The Instruction Manual that comes with the game make it clear from the outset that players must take on the values, identities, and ways of thinking of a professional soldier to play the game successfully: "Everything about your squad," the manual explains, "is the result of careful planning and years of experience on the battlefield. Respect that experience, soldier, since it's what will keep your soldiers alive" (p. 2).

In the game, that experience—the skills and knowledge of professional military expertise—is distributed between the virtual soldiers and the real-world player. The soldiers in the player's squads have been trained in movement formations; the role of the player is to select the best position for them on the field. The virtual characters (the soldiers) know part of the task (various movement formations) and the player knows another part (when and where to engage in such formations). This kind of distribution holds for every aspect of military knowledge in the game. However, the knowledge that is distributed between virtual soldiers and real-world player in this game is not a set of inert facts; what is distributed are the values, skills, practices, and (yes) facts that constitute authentic military professional practice. This simulation of the social context of knowing allows players to act as if in concert with (artificially intelligent) others, even within the single player context of the game.

In so doing, *Full Spectrum Warrior* shows how games take advantage of situated learning environments. In games as in real life, people must be able to build meanings on the spot as they navigate their contexts. In Full Spectrum Warrior, players learn about suppression fire through the concrete experiences they have had while playing. These experiences give a working definition of suppression fire, to be sure. But they also let a player come to understand how the idea applies in different contexts, what it has to do with solving particular kinds of problems, and how it relates to other practices in the domain, such as the injunction against shooting while moving.

Video games thus make it possible to "learn by doing" on a grand scale—but not just by doing any old thing, wandering around in a rich computer environment to learn without any guidance. The fruitful patterns or generalizations in any domain are the ones that are best recognized by those who already know how to look at the domain and know how complex variables in the domain interrelate with each other. In *Full Spectrum Warrior* the player is immersed in activity, values, and ways of seeing. But the player is guided and supported by the knowledge built into the virtual soldiers and the weapons, equipment, and environments in the game.

DISCUSSION: COLLABORATIVE LEARNING IN A VIRTUAL CULTURE

We began this essay by arguing that current thinking and theorizing about tools is based on an assumption about agency: that humans have it and tools don't. As a thought experiment, we replaced this postulate with an alternative borrowed from Latour: that neither tools nor humans have agency in the traditional sense; rather action always emerges from the collaboration of mutually mediating actants, which can be human or non-human. That is, we posited an ontological equivalence between *inter*activity and *intra*activity in thinking. Positing such equivalence, we argue, requires creating a new analytic category of toolforthoughts: a view from virtual culture of the relationship between technology and cognitive activity. For rhetorical purposes we describe this as a theory of distributed mind. However, we want to emphasize that our goal is not to supplant existing sociocultural theories of cognition, nor to recreate actor network theory, but to extend these theories to account more robustly for thought and action in an era of new computational toolforthoughts.

A theory of distributed mind extends current thinking about CSCL in two ways. First, if tools and persons are equivalent actants, then thinking and acting always mean learning to collaborate with valued toolforthoughts. This means that in a very important sense, all *computer-supported activity* is inherently *collaborative* activity. In an age of powerful computational toolforthoughts, this is not merely a rhetorical claim, as the example of *Full Spectrum Warrior* shows so vividly. We are constantly in collaboration with valued toolforthoughts, and even toolforthoughts designed to support human-to-human collaboration are, in fact, examples of *human-computer-human interaction* rather than computer-supported collaboration.

The second point, which follows from this first, is that as it enters its second decade of formal existence, the field of CSCL may need to broaden its mandate to focus more directly on the *ends* of human-computer-human interaction rather than its current emphasis on the *means* of using computational toolforthoughts to support human collaboration.

Our current educational system writ large is grounded in an assumption that thinking is something that goes on inside the head of a person using tools, and that what matters, in the end, is the thinking and not the using of the tools. This view privileges the use of abstract formalisms and the classes of problems those formalisms were developed to solve—neither of which have been empowering historically for students from less advantaged backgrounds. Building on work of sociocultural theorists, CSCL has expanded this view of cognition by focusing on things students can accomplish in collaboration with other students in computer-mediated social settings. But as we argue above, this step, though important, may not be sufficient.

In a theoretic culture marked by a relative paucity of powerful toolforthoughts, the most significant of which were static inscriptional systems, the goal of education was to master existing cultural tools. Accordingly, sociocultural theories have emphasized, generally, the development and use of infrastructural tools (diSessa, 2000), such as traditional mathematical notations and print literacies, within relatively stable (albeit evolving) cultures of practice. In a time of rapid and fundamental technological change it is easier to see that which toolforthoughts are valued in this sense is inherently ideological. As diSessa (2000) argues, tools become infrastructural when they support a nexus of uses that are seen as valuable and necessary in a given social context—a move that always depends on the size and power of the social niches they serve. By conceptualizing tools as participants in, rather than merely mediators of, cognition (and contrariwise by conceptualizing persons as mediators rather than agents), a theory of distributed mind prepares us for a virtual culture marked by a multiplicity of cognitive toolforthoughts. It provides perspective on the inevitable panic that arises in our theoretic frame of mind when young people begin using new and more powerful toolforthoughts: the panic that our children are no longer *learning how to think*. A theory of distributed mind foregrounds instead consideration of the kinds of actions we want students performing: Should they answer problems that computers can now easily solve? Or should they be working on problems that have not yet been solved, but that can now be approached in collaboration with a combination of able peers and new toolforthoughts? The question we ask about new toolforthoughts can no longer be: "Will these tools help students to collaboratively learn traditional mathematical, scientific, social, historical, and print literacies?" Rather, we have to ask: "Who will be able to collaborate with these toolforthoughts, and what will they be able to accomplish?"

A theory of distributed mind reminds us to be wary of the naturalistic fallacy of mistaking *what is* for *what ought to be*. The particular set technologies we have inherited—pens, papers, books—does not define a fixed and immutable realm of what it cognitively possible or desirable. So pedagogical choices are not, as Pea (1993) suggests, about balancing deep understanding and engaging tasks. Nor are they about deciding whether to emphasize "solo performance" (with or without toolforthoughts) or work "in collaboration with others." Rather, learning is always collaborative. Learning always means doing particular kinds of things in collaboration with particular kinds of toolforthoughts. Therefore all meaningful actions with toolforthoughts can lead to an experience of deep understanding. What matters are the actions we value—a value defined in relation to our understanding of the things worth doing and issues worth addressing with a given set of toolforthoughts. This decidedly preliminary examination of a theory of distributed mind thus suggests that new educational toolforthoughts cannot be evaluated in isolation; rather, they need to be understood as fundamentally changing how we think. In particular, the perspective of toolforthoughts highlights the extent to which all thinking is a collaborative enterprise, and therefore all learning—particularly computer-supported learning—is collaborative learning. Examining toolforthoughts in a virtual culture thus raises profound questions: How will we decide what activities we value? What frameworks will we use to weigh the constraints and affordances of competing toolforthoughts? And, as we move into the second decade of work in CSCL, how can we conceptualize computer-supported collaboration as being more than merely computer-supported *human* collaboration?

Eventually, of course, these questions must be developed in such a way as to be addressed by specific hypotheses that can be subjected to empirical study. Our goal here has been to provide an ontological argument for the value of such questions to the CSCL community—and to suggest that the effort of addressing them will be advance our understanding of the role computational media can and should play in collaborative learning.

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Fostering Social Presence in Asynchronous Online Class Discussions

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Abstract. The study examined the role of social presence in relation to students' perception of online asynchronous learning. Specifically, this study (a) examined the magnitude of the relationship between students' perceptions of social presence and their satisfaction with online class discussions, (b) investigated students' online behaviors which contributed to their own projected social presence, and (c) explored factors influencing students' perceptions of social presence, and the relationship between students' perceptions of others and their own projected presence in online course discussions. The study closes by exploring the implications for its findings for learning and teaching in online asynchronous learning environments.

Keywords: social presence, online communication, online learning community, web-based learning

THEORETICAL FRAMEWORK

Over the past decade, the Internet has had a profound impact on the higher education with the emergence of a new form of distance education – Asynchronous Learning Networks (ALN). The reach of the Internet enables institutions to operate whole universities (Acker, 1995; Noam, 1998), whole programs, and individual courses in the cyberspace. Concurrent with the growth in popularity of implementing ALN courses in adult education is a growing awareness and recognition of alternative theories for learning. These theories suggest there are problems with, and ineffectiveness in, the traditional ways of teaching and learning. The most prevalent theories of learning associated with ALNs are those based on social constructivist principles (Brown and Duguid 1998; Duffy & Cunningham, 1996; Lave and Wenger 1997).

A primary focus of social constructivist theory is on learning through group collaboration and knowledge building. Social constructivists contend that knowledge requires "communicating, comprehending, acknowledging and sharing through group activities and social interaction" (Brundage & MacKeracher, 1980 p.7). Through group interactions, learners encounter multiple perspectives on the topic of discussion from which they synthesize their understanding (Duffy, 1996; Jonassen, 1994; Savery & Duffy, 1995). Interaction is an essential vehicle that enables negotiation of meanings among communication participants. The interpersonal interactions in online discussions, however, tend to be complicated because they take place in an asynchronous, text-based environment (Gunawardena, 1995). A common concern among faculty and students is that the alienated nature of computer-supported programs might prevent students from experiencing a sense of community: a sense of belonging with other students, the instructor, the course and the universities (Haythornthwaite, 2002). Perhaps the most prevailing concern about the features of computer-mediated communication (CMC), from a community perspective, has been the notion that computer-mediated communication could not convey "social presence," the feeling of "being there" (Short, Williams and Cristie, 1976).

According to Short, Williams & Cristie (1967), social presence is a quality of a medium itself and an important variable influencing the person-to-person communication in the medium. They hypothesized that "the users of any given communication medium are aware of the degree of social presence of the medium and tend to avoid using the medium for interactions which requires a higher degree of social presence than they perceive the medium to have" (Short, Williams and Cristie, 1976, P65). On the basis of this assumption, they argued that text-based CMC, with its lack of nonverbal and vocal communication cues, inhibit the ability of CMC participants to exhibit the necessary social presence to achieve interpersonal relationships. However, field researchers in CMC often report findings which indicate that CMC students engaged in a group dynamic more intense and richer in relational communication than those in traditional Face-to-Face (F2F) classrooms (Walther, 1992) and that CMC provides a highly interactive and social environment which supports instructional engagement that results in student satisfaction and achievement (Boston1992; Gunawardena, 1994; Harasim, 1994; Richardson & Swan, 2000; Swan et al. 2001). Additionally, studies revealed that CMC users usually developed the ability to express the missing nonverbal cues (i.e., vocal tones and facial expressions, etc.) in written form with paralanguage[1] (Asteroff, 1987; Hiltz, 1994; Walther, 1992, Swan 2003).

An increasing number of studies have begun to examine social presence, the perception of interpersonal connections with virtual others, as an important factor in the success of online learning (Gunawardena & Zittle, 1997, Richardson & Swan, 2003, Tu, 2000, Swan 2002; Picciano, 2002). Gunawardena & Zittle (1997) developed scales to measure social presence in the computer-mediated communication context and found social presence a strong predictor of overall learner satisfaction in a text-based medium. Congruent results were found in Richardon & Swan's (2003) study; the results suggested that the students' perception of social presence in online courses was significantly related to overall learner satisfaction with the courses, students' perceived learning, and their satisfaction with the instructor. Tu (2000) proposed that social presence, which conveys feelings, perceptions and reactions to others in online discussions, was a vital element in influencing online interactions. Swan (2003) examined students' social presence behaviors through a content analysis of online discussion and found not only increased usage of these forms of written communication, but changes in their functional usage overtime. Picciano (2002) replicated previous results linking perceived social presence with perceived learning and additionally found that student perceiving the highest degrees of social presence also scored higher on written assignments.

The research reported in this paper builds on these previous social presence studies. In particular, it attempts to tease apart the perceived social presence of peers from the perceived social presence of instructors and examines their relative influences on students' satisfaction and perceived learning in online courses. It also begins to explore the relationship between perceived social presence and projected presence in online discussions and to identify factors contributing to perceptions of social presence in online courses.

METHOD

Participants

The participants were fifty-one students enrolled in four online graduate courses in educational technology taught by two instructors at a large public university in the northeast. Fifty-one (out of 91 enrolled students) volunteered to fill out an online questionnaire. Respondents ranged in age from 21 to over 50, approximately two thirds were female, and the majority had taken at least one previous online course.

Design

This study is a mix of quantitative and qualitative methods to obtain better understanding of the students' perceptions of social presence.

First, fifty-one participants were asked to answer the Social Presence and Satisfaction Scale adapted from Richardson and Swan (2003). Changes were made to distinguish between social presence of peers and the social presence of the instructors, to relate perceived learning specifically to online discussions, and to add a perceived interaction construct. The questionnaire gathered demographic information and asked respondents to rank their perceptions of the social presence of their peers and instructors, their satisfaction with their instructors, their perceived learning from online discussions, and their perceptions of interaction among course participants on five-point Likert scales. Data from the questionnaires were analyzed for relationships among the variables using correlational and regression analyses, and significant differences in perceived social presence among differing demographic and other (potentially confounding variable) groups were explored using analyses of variance.

Next, the researchers identified the five respondents with the highest and the five students with the lowest ratings for perceived social presence and grouped them (high and low) in order to examine differences in social presence behaviors and perceptions of online class discussions between the two groups. Discussion messages posted by these students were coded for social presence indicators developed by Swan (2001) using quantitative content analysis to look for the differences in the ways in which these students projected their own presences in online class discussions.

In addition, Semi-structured interviews were, conducted through e-mails and via telephone to explore these students' points of view concerning the issues interaction, instruction, and learning in online class discussions. Their responses were compared using thematic cross-case analysis to explore factors influencing their differing perceptions.

[1] Paralanguage is identified as " features of written language which are used outside of formal grammar and syntax and other features, related to but not part of written language, which through varieties of visual and interpretive contrast provide additional enhanced, redundant or new meanings to the message" (Asteroff, 1987).

RESULTS

What Is The Relationship between Perceptions of Social Presence and Students' Satisfaction with Online Class Discussions?

The questionnaire used in this research was adapted from Richardson and Swan's (2003) social presence survey. Changes were made to distinguish between the social presence of peers and that of the instructors, to relate perceived learning specifically to online discussions, and to add a perceived interaction construct. Besides questions eliciting demographic and other potential confounding variables (gender, age, course, previous online courses, proficiency in navigating and time spent in online discussion), respondents were asked to rate their agreement (on a 5-point Likert scale) with statements concerning their perceived social presence of peers (8), their perceived social presence of instructors (5), their satisfaction with the instructor (1), their perceived learning from online discussion (4), and their perceptions of the interaction among course participants (1). Ratings were aggregated across statements to yield single scores for each variable, and correlations between variables computed (*Table 1*). As in previous studies, all variables were highly correlated, indicating significant relationships among them, with the strongest correlations found between perceptions of social presence (peers and instructors), between these and perceived learning, and between instructors' social presence and satisfaction with instructors.

Table 1: Correlations Between Variables (n=51)

	SPP	SPI	PL	PI
social pres. of peers (**SPP**)				
social pres. of inst. (**SPI**)	.70*			
perceived learning (**PL**)	.70*	.74*		
Perceived interaction (**PI**)	.62*	.50*	.55*	
satisfaction w/ Inst. (**SI**)	.56*	.81*	.74*	.41*

*P<.005

These findings were confirmed by regression analyses, which also revealed the particular importance of the social presence of instructors in these relationships. Specifically, linear regression indicated that the perceived social presence of instructors predicted 49% of the variance in the perceived social presence of peers, suggesting their strong interrelationship. Multiple regressions revealed that together these two variables were significant joint predictors of satisfaction with instructors (50%) and perceived interaction (40%), but when their joint contributions were controlled for only the perceived social presence of instructors was found significant. Both variables, however, not only jointly, but also individually predicted perceived learning (61%), although the perceived social presence of instructors accounted for nearly twice (24%) the variance predicted by perceived social presence of peers (13%).

To explore other potential factors influencing perceptions of social presence, the mean scores and standard deviations for students' (combined) perceptions of social presence were compared by classes, courses, instructors, and students' demographic and experiential characteristics using analysis of variance. These analyses revealed significant difference in student perceptions only between courses and age groupings. Differences between courses (but not classes or instructors) suggests the importance of instructional design in supporting the development of social presence. Post hoc comparisons of differing perceptions among age groupings showed significant differences only between students under 26 and those over 45 suggesting that younger students were significantly more comfortable with online communication than older students and providing some support for notions of digital natives. No differences based on gender or online experience were found.

How Do Students with Differing Perceived Social Presence Project Their Own Presence in Online Class Discussions?

Combined social presence scores were also used to identify the five students perceiving the greatest and the five students perceiving the least presence of others for qualitative comparisons. The first of these involved a quantitative content analysis of the selected students' discussion postings. These were coded for social presence indicators using Swan's (2003) classifications of affective, interactive and cohesive indicators and aggregated by category using Rourke, et al's (2001) social presence density measure (*Table 2*). Social Presence Density (SPD) is a unit of indicators per 1,000 words obtained by summing the raw number of social presence indicators, then dividing by the total number of words, and multiplying the ratio by 1000.

The results of this analysis reveal that, even though the messages of students perceiving lower social presence contained 1.2 times as many words as students perceiving higher social presence, their messages contained far fewer social presence indicators. They suggest, then, that the perception of social presence is related to its presentation.

Table 2: Social Presence Densities by Group (n=10)

	affective	interactive	cohesive	total
low SP group	17.5	6.7	4.4	**28.6**
high SP group	**26.3**	**10.0**	**6.0**	**42.3**

How Do Students with Differing Perceived Social Presence Perceive Their Online Class Discussions?

Students identified as perceiving particularly high and particularly low social presence were also interviewed concerning their perceptions and their experiences in online discussions. Their answers were reviewed for emergent themes and compared across groups using cross case analysis. The qualitative findings support quantitative comparisons between these groups (*Table 3*) and elaborate on them. Themes that emerged included perceived learning from online discussion and perceived interactions within it.

Table 3: Mean Perception Rating by Group (n=10)

	perc. learning	perc. interaction	perc. SP of instructors	instructor satisfaction
low SP group	3.2	3.0	3.7	**4.0**
high SP group	**4.8**	**5.0**	**4.9**	**5.0**

Students who perceived high social presence in the online discussions also believed they learned more from it than did students perceiving low social presence. Comparative analyses of students' interview transcripts revealed meaningful differences in the quality of student perceptions as well. Students in the high social presence group attributed their learning to the contributions of others. They reported benefiting from the ideas of others and the multiple perspectives presented. In contrast, students in the low social presence group attributed their learning from online discussion to their own efforts, stating that they learned by articulating their own thinking in writing their messages.

Comparative analysis of interview responses also revealed differences between groups relative to their perceptions of four categories of online interactions. For example, although all students reported changing their communication styles to adjust to the discussion interface, students in the high social presence group adapted a less formal, more personal and expressive tone, while the low social presence students reported adopting a more formal tone. Similarly, although all students appreciated that discussion questions asked them to relate course content to their own experiences and stated they found this helped them better understand concepts, high social presence students also found this useful for getting to know their classmates, whereas low social presence students were disappointed in their peers' responses, finding them mostly "a waste of time." Indeed, while high presence students found peer interactions "stimulating" and reported developing personal relationships with some students, low social presence students found discussions "uninteresting" and did not develop any interpersonal relationships with their classmates. Finally, although all but one student interviewed reported very positive interactions with their instructors, there were meaningful differences between their perceptions and the one student who felt his instructor was distant. Specifically most students reported that their instructors fostered community building through regular interaction, personal sharing, constructive and prompt feedback, and the encouragement of students' knowledge building efforts. The student with negative perceptions of instructor interaction believed that his instructor should have been more in control of the discussions

EDUCATIONAL SIGNIFICANCE

The results of this study not only extend our understanding of both the importance and the nature of the development of social presence in online course discussions, but suggest ways to support such development. Specifically, they highlight the importance of instructor presence, instructional design, and students' own presentation of themselves in online discussion. They suggest that social presence can be fostered through pro-social instructor behaviors and careful design of online discussions, as well as faculty development focusing on social presence issues. In addition, they suggest that explicit training for students in the importance of social presence, ways of presenting themselves online and the nature of online discussion might help particular students better adapt to the medium. As this and previous studies have demonstrated links between perceived social presence and learning, such findings have both theoretical and practical significance.

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Instructional Methods for CSCL: Review of Case Studies

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Abstract. The purpose of the present study is to provide instructional methods for collaborative learning in computer-supported learning environments which would be useful information for CSCL researchers, instructional designers, and online instructors. Although several researchers have provided instructional design theories and guidelines for collaborative learning in traditional classroom environments, there are a few instructional design studies developed specifically for collaboration in online learning environments. This study critically reviewed and analyzed ten case studies to identify instructional goals, methods, effectiveness, and conditions of collaborative online learning. Twenty-three methods identified from the synthesis and comparison of cases were grouped into five categories representing commonalities: a) grouping, b) collaborative tasks, c) team-building, d) computer-mediated communication, and e) instructor. It appeared that while some methods are equally important for both face-to-face and computer-supported learning environments, instructional methods related to group composition, synchronous interaction, and communication modes are particularly critical for collaborative online learning.

Keywords: collaborative learning, instructional method, case survey

INTRODUCTION

During the past decade, there has been a significant movement toward distance education. Recent statistics show that more than 80 percent of public institutions in the United States offer either online or blended courses (Allen & Seaman, 2003). Conventional lecture-based courses are restructured with web-based components to solve problems related to overworked faculty, over-capacity, and lack of interaction (Tiangha, 2003). With more courses being offered via online learning formats, it is becoming important to improve the quality of learning experience in distance learning environments. Educators have tried to incorporate collaborative learning methods in their distance education courses with the belief that increased interaction among students could enhance learning outcomes and student satisfaction. Specifically, the use of two-way computer-mediated communication (CMC) has made collaborative learning possible among students in geographically different areas.

Despite the popular support for collaborative learning strategies, previous research has suggested that students are often dissatisfied and frustrated with their collaborative learning experiences in distance learning environments (Hara & Kling, 1998). It is clear that assigning students to groups does not necessarily mean that they will work collaboratively. Collaborative learning should be structured under the full understanding and consideration of grouping strategies, team-building activities, collaborative tasks, online discussions and evaluation methods.

PURPOSE OF THE STUDY

The purpose of the present study is to provide instructional design methods for the improvement of the quality of learning processes and outcomes in collaborative online learning. Although several researchers have provided instructional design theories and guidelines for collaborative learning in traditional classroom environments, there are a few instructional design studies which discuss theory- and conditional-based methods for collaboration in computer-supported learning environments. This study thoroughly reviewed and analyzed ten case studies to identify instructional goals, methods, effectiveness, and conditions of collaborative online learning. The instructional methods provided in this paper could be a valuable resource for computer-supported collaboration learning researchers, instructional designers, and online instructors who want to create successful collaborative learning environments, where students gain critical thinking, problem-solving, and interpersonal communication skills through learning processes.

LITERATURE REVIEW

Collaborative Learning

The social-constructivist view of learning argues that people construct their knowledge through negotiating meanings with others. According to Vygotsky (1978), a person's cognitive development is highly dependent on their relationship with others. His idea of the *Zone of Proximal Development* (ZPD) – "the distance between actual or independent problem solving and performance when provided with learning assistance from adults or more capable peers" (Bonk & Cunningham, 1999, p. 36) – proposes that people construct their knowledge through social interaction and collaboration with others. As an example, students with low ability levels may be able to reach their ZPD with a help of advanced and high-achieving peers.

Collaborative learning is one instructional strategy used for the social construction of knowledge and skills. The advantages of collaborative learning are abundant from social to cognitive and affective ones. First, collaborative learning environments provide opportunities for students to experience multiple perspectives from others who have different backgrounds. Students can develop critical thinking skills through the process of judging, valuing, supporting or opposing different viewpoints (Fung, 2004). Second, individual students can develop social and inter-personal skills which are critical to be successful in modern society. Third, collaborative learning approaches can provide students with an affective support and a sense of belonging, which promote student participation and community-building (Stacey, 1999).

Some researchers use collaborative learning and cooperative learning interchangeably, but it is important to understand differences between the two terms. While collaborative learning places an emphasis on mutual engagement to reach a common group goal, cooperative learning uses a task specialization approach where students take divided tasks and then their results are combined into a final product. (Abrami & Bures, 1996; Bernard, et. al., 2000; Kitchen & McDougall, 1998). Unlike collaborative learning, cooperative learning provides fewer opportunities to develop mutual engagement, knowledge and skill exchange, and interpersonal communication skills.

Quality of Collaborative Learning in Distance Courses

While a number of research studies examined students' affective learning experiences such as satisfaction, dissatisfaction, anxiety and frustration with distance education courses (Conrad, 2002; DeBourgh, 1999; Hara & Kling, 2000), there is a dearth of literature which specifically focuses on student satisfaction with collaborative online learning. Possible reasons for this phenomenon may be found from the study by Hara and Kling (2000). First, students may not have opportunities to express their negative feelings about distance learning. Hara and Kling suggested that although students experienced several problems in distance learning processes, they might not be able to express their true feelings due to the relief from the course, concern about their instructor's feeling, and limited time for the course evaluation. Another reason is that researchers may have extremely positive views of collaborative learning and distance education, and assume that students are satisfied with the quality of collaborative online learning. In fact, collaborative learning has been regarded as an effective instructional method in traditional classroom learning. Nevertheless, it is questionable whether the collaborative learning approach can yield equally effective learning outcomes in distance learning situations.

Although some researchers have examined student perceptions of and experiences with collaborative online learning, they yielded inconsistent results in terms of the level of students' satisfaction. A research study by Kitchen and McDougall (1999) examined how graduate students perceived the educational value of collaborative learning delivered on the Internet. The results indicate that although students expressed some negative responses, the majority of students rated their collaborative experiences as good or excellent. Similarly, Jung, Choi, Lim and Leem (2002) reported that students who participated in collaborative online tasks expressed higher levels of satisfaction with their learning process compared to those who engaged in task-oriented interaction with their instructor.

In addition to the level of satisfaction, researchers have investigated important factors affecting the perceptions of student satisfaction with collaborative online learning. No significant correlations were found between students' satisfaction and their background characteristics such as age, gender, grade level, and computer literacy (Kitchen & McDougall, 1998; Yaverbaum & Ocker, 1998). Prior studies suggest that students are likely to be dissatisfied and frustrated with the following factors: (a) unclear expectations from instructors, (b) tight timeline, (c) workload, (d) poor software interface, (e) slow access, and (f) no synchronous communication (Gaddis, Napierkowsk, Guzman, & Muth, 2000; Kitchen & McDougall, 1998).

RESEARCH METHODOLOGY

Case Survey

Instructional guidelines are often developed from a synthesis of relevant research literature on certain topics, and also from instructional designers' practical experiences. In this study, a case survey method was employed to aggregate, compare and synthesize instructional strategies regarding student collaboration in online learning environments. The case survey is a useful research method to aggregate findings across a large number of case studies (Lucas, 1974). The method is parallel to a questionnaire survey in which several cases are analyzed and categorized according to common factors (Cunningham, 1997). Beatty (2002) used the case study method to develop a situational framework for selecting instructional methods that engage learners in social interaction. In the present study, case studies which examined collaborative learning in computer-mediated learning environments were analyzed and compared in terms of instructional goals, methods, conditions, and effectiveness.

Case Collection

Ten case studies were selected from several academic search engines (See Appendix A for the list of references). Three criteria were used to locate relevant articles. First, key words 'collaborative online learning', 'collaborative learning', 'cooperative learning', 'online collaboration' and 'group interaction' were used to identify articles. Case studies that describe solely student-student social interaction without engagement in collaborative learning tasks were excluded in the process of case selections since the focus of the present study is placed on instructional interaction among students. Second, articles published in peer-reviewed journals were selected to ensure the validity and reliability of research methods. Third, only case studies with publication dates of 1998 or later were selected as shown in Table 1. Since distance education has undergone changes with advances in modern communication technologies, recent articles are likely to use sophisticated and accessible technologies to reduce technical problems.

Table 1 Publication Dates

Year	1998	1999	2000	2001	2004
Number of case study	1	2	4	1	2

Case Analysis

Information gathered from each case study was critically reviewed and recorded for comparison and synthesis across cases independently by the two authors (See Appendix B). Any disagreements on case analysis were resolved through discussions until an acceptable rate of agreement was reached. Specifically, each case study was analyzed by answering the following questions used to develop instructional design theories (Reigeluth, 1999):

1. Instructional Situations
   - Learning: What is the type of learning content?
   - Learner: What are the student characteristics?
   - Learning environment: What are the collaborative learning environments (e.g. group composition, group size, collaborative tasks, etc.)?
   - Development constraints: What are the constraints (e.g. CMC tools, time, expenses, etc.) for the development of collaborative learning methods?
2. Instructional Methods
   - Effectiveness: What instructional methods are effective or not effective?
   - Conditions: What are the instructional conditions necessary for the effectiveness of a certain instructional method?

Although this study did not aim to develop a comprehensive instructional design theory, using the framework suggested by Reigeluth (1999) provided an initial point to identify effective instructional strategies and particular situationalities.

RESULTS

All the ten cases were cross-analyzed to identify common patterns of learning goals, situations, and instructional methods for collaborative learning in computer-supported learning environments. Classification schemes were created to categorize multiple cases based on the presence of commonalities. What follows is a synthesized description of a) the learning goals, b) instructional conditions, and c) instructional methods for collaborative online learning.

Learning Goals

The goals reported in the case studies were classified into the following five major categories:

- Creating learner-centered and collaborative learning environments
- Encouraging students to learn critical-thinking, problem-solving, and interpersonal communication skills
- Acknowledging the importance of respecting, accepting, and negotiating multiple perspectives in learning processes
- Cultivating a learning community where students share and learn new knowledge and skills from each other
- Developing authentic, active, and relevant learning experiences for student motivation and engagement

Table 2 presents the goal categories and the numbers of cases in each category.

Table 2 Goals and Cases

Learning goal	**Cases**
Learner-centered learning environment	C2 C3 C4 C7 C8
Critical thinking	C1 C6 C7 C10
Multiple perspectives	C5 C6 C7 C10
Learning community	C2 C8
Authentic learning experience	C1 C7

Instructional Conditions

Learning

The collaborative learning approach is the best appropriate for complex problems and authentic tasks providing students with meaningful and relevant experience that they would encounter in their work environments (McAlpine, 2000). The complexity of collaborative tasks can encourage students to exchange their ideas, to negotiate different understandings, and to develop agreed solutions. Through this process, student can learn how to apply basic knowledge and skills to real situations. Thus collaborative learning is not appropriate for tasks that require a single answer and can be effectively taught by direct instruction (Nelson, 1999).

Learner

Collaborative learning may not be appropriate for all students. When students do not have previous experience with complex problem-solving and authentic tasks, they are not likely to actively participate in a group learning process, and their learning can be very superficial. In addition, since students in online courses are typically more diverse than traditional courses in terms of age, language and culture, students should have abilities to accept and negotiate multiple viewpoints of group members. Participants in all the ten cases in this study were adult learners studying in higher education institutions. Adult learners are reluctant to be dominated by a group leader or a instructor, and want some self-control and self-direction in their learning process (Kitchen & McDougall, 1998). For instance, students in Case 6 expressed negative reactions to their instructor's intervention and felt that they were constantly watched for evaluations.

Learning Environment

The inquiry-based learning environment, where students explore and exchange several ideas to find a solution, is the most conducive to collaborative learning (Duffy, Dueber & Hawley, 1999). Clearly, in this environment, students take responsibility for their learning and instructors provide necessary guidance. The nature of online courses should be considered to design a truly collaborative learning environment. It is important to consider students' diverse characteristics and backgrounds for the size and composition of groups.

Development Constraint

In most cases, the use of collaborative online learning necessitates student access to computer, the Internet, and CMC technologies. It appears that the technologies should support students to effectively plan, coordinate, and implement collaborative learning. Several commercial technologies are available for collaborative learning, but they allow little flexibility for customization. And the design and development of sophisticated collaborative technologies require considerable investment on time and money.

Instructional Methods

This section presents instructional guidelines and strategies to facilitate collaborative learning in computer-mediated learning environments. A total of 28 methods were initially identified in the ten case studies, and then were grouped into the five general themes that emerged from the comparison of the cases: (a) grouping, (b) collaborative task, (c) team-building, (d) computer-mediated communication, and (e) instructor's role. As shown in Table 3, the final guidelines include 11 instructional methods necessary for collaborative online learning.

Table 3 Instructional Guidelines for Collaborative Online Learning

I.	**Grouping** Form small groups. From homogenous and/or self-selected groups.
II.	**Collaborative Task** Embed authenticity, relevance and meaningfulness. Require individual accountability.
III.	**Team-Building** Promote opportunities for face-to-face interaction. Engage in online 'get to know you' activities.
IV.	**Computer-Mediated Communication** Provide multiple channels of CMC for effective group communication. Create shared group spaces. Motivate students to participate in online discussions. Minimize technical problems.
V.	**Instructor** Act as a facilitator, guider and coordinator.

Grouping

Form small groups. The first important step in collaborative online learning is to decide the size of groups, which plays a significant role in group dynamics. The size of the group should be small enough to prevent students from free riding, and at the same time, each group should have a sufficient number of members for active discussions and participation (Graham, Scarborough & Goodwin, 1999). Small group sizes are effective in that students can feel comfortable expressing their ideas and receiving social support (Stacey, 1999). Particularly, when students are novices in content areas taught, small groups may provide students with high comfort levels in the process of constructing new knowledge.

Form homogenous and/or self-selected groups. Several cases examined in this study show that collaborative learning is effective when students are grouped under the consideration of gender, age, language, educational and cultural backgrounds, and technical experiences. Specifically, when online courses are offered to students from different geographical areas and cultural backgrounds, it may be effective to form homogeneous groups rather than heterogeneous ones (Ragoondaden & Bordeleau, 2000). While students can have valuable opportunities to learn multiple perspectives from others with different backgrounds, homogeneous grouping can alleviate frustrations and problems due to delayed feedback, different languages, and ineffective communication. In Case 1, students around the world, Canada, France, Belgium, Switzerland, Mauritius and Reunion, worked collaboratively on assignments, but the diversity of written languages hampered collaboration among students.

Instructors can administer a simple survey to gather information regarding student preferences, interests, living areas, primary languages, and so forth, before online classes begin. If possible, students should have options to select their own groups and topics. Two studies (Case 2 and Case 4) suggest that students in self-selected groups were effective in their collaborative work because members shared similar interests and purposes, and actively participated to achieve common goals.

Collaborative Task

Embed authenticity, relevance and meaningfulness. As mentioned earlier, collaborative learning is the most appropriate with authentic problems (Carr-Chellmana, Dyer & Breman, 2000; McAlpine, 2000). Cases 1 and 7 present useful examples regarding how authentic tasks were used for collaborative learning. In Case 1, students worked with subject matter experts to solve complex instructional design problems identified in real learning situations. Students in Case 7 worked collaboratively on real-world scenarios in business settings. McAlpine (2000) suggests that an important advantage of real-world projects is that students have opportunities to learn how to share and accommodate multiple viewpoints. Furthermore, the authenticity of collaborative tasks may become more important for students studying in academic areas where the primary goal is to acquire and apply skills and knowledge required in real work environments.

In addition to authenticity, the collaborative tasks should provide students with relevant and meaningful learning experiences (Fung, 2004; Stacey, 1999). Students in Case 3 did not actively participate in collaborative online discussions although instructors and moderators encourage their participation. Fung (2004) suggests that a main reason for the lack of student interest in online group work was broad and unstructured questions. Student participations in collaborative learning may become more active when they can see the connection between group tasks and personal interests (e.g. career goals and academic interests).

Carr-Chellmana, Dyer and Breman (2000) argue that authentic tasks require complex problem- solving skills, which cannot be learned in a short duration of time. Thus students without prior experiences in authentic and collaborative tasks may experience difficulties in the group problem-solving processes. To provide students with opportunities to develop problem solving skills, it is effective to start with a simple problem and then to gradually build complexity into subsequent collaborative tasks (Fung, 2004; Nelson, 1999).

Require individual accountability. Individual accountability should be ensured and assessed for active participation and group cohesion (Murphy, Mahoney & Havell, 2000; Stacey, 1999). Case 8 presents an example of group contracts or group management plans which were used to specify the communication methods, primary roles, emergency plans, project timelines, and so forth. In this example, the instructor provided a template of group contracts to reduce the amount of time that groups have to spend planning, and the group contracts were modifiable with the approval of members.

In addition to the use of group contracts, instructors may encourage groups to regularly reflect on and report group progress and dynamics. The reflection or report, however, should not be used such that students are concerned about group cohesiveness and privacy (Kitchen & McDougall, 1998). Students in Case 6 expressed that a reflection paper commenting on their group processes and other members' participation caused some concern regarding group cohesiveness.

Grading is an important issue related to individual accountability. When students engage in both individual coursework and collaborative work, students may focus more on individual assignments than on group projects that demand extensive time and effort. As an example, Case 9 shows that student participation in collaborative learning decreased as the course progressed, simply because individual assignments were worth most of the final grade. Thus it is important for instructors to find an effective balance of grading between group work and individual tasks.

Team-Building

Promote opportunities for face-to-face interaction. The online learning environment has been criticized for its lack of human interaction. Due to this reason, there is an increasing movement toward blended learning approaches where students can have opportunities for both online and face-to-face interaction with their instructors and classmates (Allen & Seaman, 2003). It appears that the blended method is also effective in facilitating the process of collaborative online learning (Carr-Chellmana, Dyer & Breman, 2000; Gabriel, 2004; Graham, Scarborough & Goodwin, 1999). In Cases 1, 4 and 5, face-to-face meetings provided students with opportunities to know other members and to build group cohesiveness for subsequent collaborative work. This method, however, may not be efficient and effective in online courses where a significant number of students have full-time jobs or live in geographically diverse areas. Carr-Chellmana, Dyer and Breman (2000) suggest that some students disliked the expense and time of traveling to attend on-campus instruction.

Engage in online 'get to know you' activities. When it is not feasible or efficient to have face-to-face meetings, instructors should design online 'get to know you' activities where students post their brief introductions and also respond to others (Curtis & Lawson, 2001). Providing one or two early synchronous CMC sessions may be useful for students to have opportunities to introduce themselves and receive immediate feedback. In addition, ice-breakers, collaborative-game types of activities can be posted online to help students gain an initial experience with the process of group collaboration.

Computer-Mediated Communication

Provide multiple channels of CMC for effective group communication. Online collaboration is not possible without the use of CMC tools, which affect the success and effectiveness of group communication. While asynchronous CMC tools, including email and online discussion boards, have been the most popular methods, students may feel the need for synchronous communication. Case 1 shows that, as group projects progressed, some students started to talk via phone because asynchronous CMC tools were not sufficient and effective for group communication. Providing multiple channels can be particularly effective when there is a need for accommodating student preferences for different communication styles. While some students may choose to use public methods of communication, some may prefer to use private modes of communication such as email, phone or face-to-face meeting.

Create shared group spaces. The use of complex and collaborative tasks often requires groups to find additional information to reach solutions (Curtis & Lawson, 2001; McAlpine, 2000). It is essential to provide groups with online spaces where group members can actively present information and share necessary resources. The design of group spaces is important because it should give both flexibility and privacy. For instance, Duffy, Dueber and Hawley (1998) suggest that online group spaces need to be designed that only group members can access or the rest of class can have limited read-only access.

Motivate students to participate in online discussions. An online discussion board is often used as a space where students can exchange, share and debate their ideas. Case 3, however, presents an example that students did not actively participate in online discussions due to a lack of structure provided by instructors. For a truly interactive and collaborative learning environment, Cases 3 and 8 suggest that it is important for instructors to require specific expectations with respect to the frequency and length of postings.

Fung (2004) argues that scaffolding strategies can be used to encourage students' participation in collaborative online discussions. For instance, instructors or group moderators can initiate a discussion of a simple topic stimulating students' interests, and then proceed to increasingly complex questions. The characteristic of discussion topics is also an important factor affecting the success of online discussions. To encourage students' intrinsic motivation for participating in discussions, Case 3 shows that it is important to select appealing and focused questions rather than being vague and broad.

Minimize technical problems. Students often face technical difficulties due to the nature of online learning environments, which highly rely on technology for communication. Technical problems (e.g., access, software interface and conferencing tools) are negatively related to student satisfaction levels with collaborative learning. To make students feel comfortable using CMC tools, instructors can offer training sessions or written guidelines at the beginning of the course. Additionally, appropriate and immediate technical support should be provided to students who experience technical difficulties impeding their learning processes.

Instructor

Act as a facilitator, guider and coordinator. Instructors in collaborative online learning environments should play roles as facilitators who provide guidance, feedback and support (Curtis & Lawson, 2001; Fung, 2004; Kitchen & MCDougall, 1998). Often, collaborative online learning requires instructors to prepare several instructional materials necessary to facilitate group works. When instructors plan to assign students to groups, project topics and roles should be clearly prepared in advance for effective planning. Additionally, instructors can develop templates for group contracts and management plans as guidelines that students use to decide individual accountability and role (Murphy, Mahoney & Havell, 2000).

CONCLUSION

While several researchers have developed instructional design theories to promote and facilitate student collaborations in face-to-face learning situations, there is a lack of instructional guidelines specifically developed for collaborative learning in computer-mediated environments. The present study critically reviewed and analyzed ten case studies to identify effective instructional methods that facilitate the learning process of online collaboration. Methods were grouped into five categories that consistently emerged from the synthesis and comparison of cases. It appears that some collaborative learning methods successfully implemented in face-to-face classrooms are equally effective in online learning environments. Small group sizes, authentic tasks, individual accountability, and team building are critical methods that have to be considered for both traditional and online collaborative learning.

However, there are some collaborative learning methods particularly critical in online learning environments. First, instructors should accommodate students' different characteristics and backgrounds in deciding the composition of groups since students in online course are diverse in terms of their work, academic and cultural backgrounds. Second, it is clear that the role of a technology medium becomes more important in online courses than in face-to-face ones. Synchronous and asynchronous CMC tools play a critical role in facilitating the process of group communication and dynamics. Thus instructors should support students to feel comfortable using different communication tools, and, if necessary, provide appropriate support related to technical problems. Finally, it appears that the use of face-to-face or online synchronous interaction is effective in building group identify and cohesiveness among members. This method, however, should be carefully planned for students who have full-time jobs and live in different time zones.

In conclusion, the use of collaborative learning in online learning environments should be planned and implemented based on the pedagogical consideration of grouping strategies, collaborative tasks, team-building activities, CMC tools, and instructor's roles. Although the intent was not to provide a comprehensive instructional design theory or guidelines, online instructors, instructional designers and CSCL researchers should consider the eleven instructional methods presented in this study to facilitate or study students' collaborative learning processes in online environments.

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APPENDIX A: TEN CASES EXAMINED IN THIS STUDY

Case 1

Carr-Chellman, A., Dyer, D., & Breman, J. (2000). Burrowing through the network wires: Does distance detract from collaborative authentic learning? *Journal of Distance Education*, *15*(1). Retrieved October 31, 2004, from http://cade.icaap.org/vol15.1/carr.html

Case 2

Curtis, D. D. & Lawson, M. J. (2001). Exploring collaborative online learning. *Journal of Asynchronous Learning Network, 5*(1), 21-34.

Case 3

Fung, Y. H. (2004). Collaborative online learning: interaction patterns and limiting factors. *Open Learning, 19*(2), 135-149.

Case 4

Gabriel, M. A. (2004). Learning together: Exploring group interactions online. *Journal of Distance Education, 19*(1), 54-72.

Case 5

Graham, M., Scarborough, H., & Goodwin, C. (1999). Implementing computer mediated communication in an undergraduate course- A practical experience. *Journal of Asynchronous Learning Network, 3*(1), 32-45.

Case 6

Kitchen, D., & McDougall, D. (1998). Collaborative learning on the Internet. *Journal of Educational Technology Systems, 27*(3), 245-258.

Case 7

McAlpine, I. (2000). Collaborative learning online. *Distance Education, 21*(1), 66-80.

Case 8

Murphy, K. L., Mahoney, S. E., & Havell, T. J. (2000). Role of contracts in enhancing community building in Web courses. *Educational Technology & Society, 3*(3). Retrieved October 31, 2004, from http://ifets.ieee.org/periodical/vol_3_2000/e03.html

Case 9

Ragoonaden, K. & Bordeleau, P. (2000). Collaborative learning via the Internet. *Educational Technology & Society, 3*(3). Retrieved October 31, 2004, from http://ifets.ieee.org/periodical/vol_3_2000/d11.html

Case 10

Stacey, E. (1999). Collaborative learning in an online environment. *Journal of Distance Education, 14*(2). Retrieved October 31, 2004, from http://cade.icaap.org/vol14.2/stacey.html

APPENDIX B: AN EXAMPLE OF CASE ANALYSES

Case 1

Carr-Chellman, A., Dyer, D., & Breman, J. (2000). Burrowing through the network wires: Does distance detract from collaborative authentic learning? *Journal of Distance Education*, 15(1). Retrieved October 31, 2004, from http://cade.icaap.org/vol15.1/carr.html

1. Instructional Conditions
   - *Learning*: Introduction to instructional design, using real-world projects to conduct instructional design activities
   - *Learner*: 23 students enrolled in a distance Instructional Technology program
   - *Learning environment*: The course was delivered via both traditional and online formats.
   - *Development constraints*: Traditional residential courses were converted to online courses.

2. Instructional Methods

   2.1. Student attended an on-campus workshop for three days.
   - *Effectiveness*: Face-to-face interactions helped students know each other, and built close relationships for subsequent group work.
   - *Condition*: Students must manage their time to attend the fact-to-face workshop.

   2.2. Students used both online (e.g., email, Web, chat) and audio (e.g. phone) communication tools.
   - *Effectiveness*: Students found that email or Web was not sufficient for effective communication among group members.
   - *Condition*: Students must manage their schedules for phone conversations.

   2.3. Authentic problems were used as group projects.
   - *Effectiveness*: Compared to students in a traditional course, distance students expressed high satisfaction with the authenticity of group projects.
   - *Condition*: Students must have prior experiences with collaborative learning and problem solving in authentic situations. It is useful to starting with a simple problem rather than giving a complex problem since students learn problem solving and collaboration skills in stages.

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Understanding Computer Mediated Social Experience: Implications for CSCL

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Abstract. A group of 9 graduate students and one faculty member formed an extra-curricular study group to explore the social nature of online learning. Following a review of literature and adopting Strauss's (1993) framework for coming to understand social activity, the group collected and analyzed interview reports of experiences of social learning and online systems. The results include five categories of responses: 1) task engagement, 2) social engagement, 3) environment engagement, 4) goal or motivation and 5) role of expert. The paper presents the positive and negative statements about social engagement and the role of expert in gaming and learning experiences and in online and face-to-face experiences.

Keywords: online learning, face-to-face learning, networked multiplayer games, social engagement, role of the expert

INTRODUCTION

Situativity theories emphasize the social nature of cognition and learning (Barab & Duffy, 2000; Brown, Collins, & Duguid, 1989; Resnick, 1987). Lave and others (Lave, 1988; Lave & Wenger, 1991) using anthropological approaches have shown that meaning and identity are constructed from social interactions. Wenger's Social Theory of Learning (Wenger, 1998) argues that we learn through participation in activities and that knowledge can be best understood as our ability to contribute to valued practices. Participating in a social unit provides meaning to experiences and activity, and provides shared perspectives and resources for sustaining engagement in activity. Thus the social nature of experience provides motivation for engagement, leads to joint enterprise, and shapes what is learned.

Online learning is a growing part of higher education, both as distance learning and as supplements to traditional coursework. Simultaneously with the increase in use of asynchronous instruction, technological capabilities for enabling new social mechanisms for participation and contribution via the Internet are advancing. However, most course management tools and implementations of online learning focus on information exchange and fail to support the interactive and social processes of teaching and learning. Online learning is often criticized by students as lacking the vitality and spontaneity of the face-to-face classroom. Understanding how students experience online learning, how they participate and contribute, and how to best enable participation in online learning are key challenges for the development of online learning systems and practices that will support collaborative and social learning.

This study seeks to build new knowledge about how students participate in online learning and how they experience the social nature of computer mediated environments (Dourish, 2001). Following Strauss's guidance (1993) for how to formulate, elaborate and present a "theory of action," the work presented in this paper is an early step in formulating a theory of online interaction (or social computing) in education. For Strauss, individual practices and meanings are defined by the social worlds in which they take place. Strauss's work and other social interactionists (Dewey, 1934 & 1938; Goffman, 1967; Mead, 1938) argue for understanding how participants experience their social world and their collective activities.

This paper presents results from interviews about the experience of playing networked multiplayer games, participating as a student in online learning courses, and participating as a student in face-to-face traditional classrooms. Networked multiplayer games represent online social activity with learning outcomes but without explicit educational objectives. Online learning systems represent online social activity with explicit educational objectives. And, traditional courses represent face-to-face social activity with explicit educational objectives. We reasoned that by examining and comparing online learning with networked games, which are recognized as highly engaging, we would develop insights about how participation is developed and sustained. Similarly we reasoned that by examining and comparing online learning with face-to-face learning, for which instructors and students have many models and substantial experience, we would develop insights about how social environments are used to facilitate learning. Thus, the purpose of examining these three domains of social activity was to identify important dimensions of how technology mediates social experience and how the social nature of activity motivates participation and supports learning.

LITERATURE REVIEW

Research has shown that effective teachers have a number of pedagogical approaches to help students socially construct knowledge through discourse and collaboration in face-to-face classrooms (Kumpulainen & Wray, 2002; Lemke, 1990; Rogoff, 1990). Rovai (2002) compared seven traditional face-to-face courses and seven online university courses delivered by a typical course management system. He found no differences in sense of community (including spirit, trust, interaction and learning) between the groups, but discriminant analysis showed student perceptions of the importance of learning, thinking critically in the course, safety and acceptance were higher in the online courses, whereas student perceptions of friendship, group identity, connectedness, similarity of learner needs, and absence of confusion were higher in the traditional courses. Pérez-Prado and Thirunarayanan (2002) also explored students' perceptions of learning experiences by comparing an online and a face-to-face section of the same university course. Students in both sections indicated that interacting with peers fortified the learning process and made learning more enjoyable; but only students in the face-to-face section indicated that they were affectively stimulated by certain class activities and interactions. Swan's (2002) research showed students participating in online discussions strove to increase social presence by using text-based verbal immediacy behaviors to reduce the psychological distance they felt in the online course. Her findings also indicated student satisfaction, perceived learning, perceived interaction with the instructor, and perceived interaction with peers were highly interrelated. That is, the more interaction students believed they had with the instructor and other students, the more they were satisfied with their course, and the more they thought they learned. Additionally, students' social ability has been identified as an important attribute for supporting meaningful interactions in online learning environments (Laffey et. al., 2005). In Laffey et al.'s study, students perception of their social ability was found to differ across course types: primarily self-paced, teacher guided instruction, and collaborative interactions with peers.

Several studies have examined the social side of networked multiplayer gaming (e.g., Choi & Kim, 2004; Ducheneaut & Moore, 2004a; Ducheneaut & Moore, 2004b; Steinkuehler, 2004). These research efforts highlight the importance of the social dimension of gaming and the social skills of game players for developing customer loyalty with games. Steinkuehler (2004) found that game players learned a new game and developed their expertise through interaction with more knowledgeable and skilled game players. In addition, Ducheneaut and Moore (2004b) found that social interactions were further encouraged by the use of buddy lists among game players. Social interactions in networked gaming environments are experienced as immediate and intuitive. For instance, game players received immediate feedback about their performance from other players and the system to improve their gaming skills (Steinkuehler, 2004). In addition, they are also socialized in the game (Ducheneaut & Moore, 2004b). Players learned how to effectively communicate and collaborate with other players by using different communication tools in order to accomplish game tasks.

METHODOLOGY

The sample included 18 subjects in a higher education setting who were expected to have experience with gaming and courses. The demographic information for participants is shown in Table 1.

Table 1: Demography of Participants

Gender	n	%	Age	n	%	Background	n	%	Status	n	%	Experience with mode	n	%
Male	13	72	20-24	6	33	American	9	50	Undergraduate	2	11	Exp with all modes	12	67
Female	5	28	25-29	4	22	Inter-national	9	50	Graduate	14	78	Exp with F2F and online courses	3	17
			30-32	8	45				Employees	2	11	Exp with F2F course & games	2	11
												Exp with games	1	5
Total	18	100		18	100		18	100		18	100		18	100

Interviews were conducted via telephone, face-to-face, or electronic messaging. The interview was semi-structured and included 21 questions designed to elicit participant's experiences in networked multiplayer games, online learning, and face-to-face classrooms and to gather subjects' perspectives on similarities and differences among those experiences. Sample interview items include: 1) Tell me about the experience and what it was like in the game (or course); 2) How did you interact with other people in the game (or course)?; and 3) Do you see similarities or differences between courses and games? In each mode subjects were prompted to think about their favorite game or course to discuss. All interviews were transcribed and imported into Nvivo for coding and categorizing student experiences. Five researchers reached consensus about the coding scheme through negotiation followed by examining the valence of the statements and counting its frequency based on categories in each mode.

RESULTS

Table 2 shows the 5 categories used to code and cluster the interview statements made by respondents. The first number represents the frequency of statements and the second number, in parenthesis, indicates how many of the 18 subjects made a statement that fits in the category. Due to page limitations, only the results categorized as social engagement and the role of expert will be discussed in this paper.

Table 2: Codes and Categories of Interview Statements

Category	Experience in Networked Multiplayer Game		Experience in Online Course		Experience in Face-to-Face Course	
	Positive Statements (No. of Subjects)	Negative Statements (No. of Subjects)	Positive Statements (No. of Subjects)	Negative Statements (No. of Subjects)	Positive Statements (No. of Subjects)	Negative Statements (No. of Subjects)
Task Engagement	22 (10)	7 (5)	19 (13)	3 (3)	10 (7)	8 (8)
Social Engagement	10 (6)	5 (3)	6 (6)	13 (7)	9 (7)	3 (3)
Environment Engagement	7 (6)	8 (8)	6 (6)	6 (6)	1 (1)	3 (3)
Goal or Motivation	7 (7)	1 (1)	3 (3)	2 (2)	5 (5)	0 (0)
Role of Expert	1 (1)	0 (0)	4 (4)	3 (3)	11 (6)	1 (1)

Social Engagement

Respondent descriptions of gaming experiences included numerous comments about the enjoyment and excitement of its social nature both as a competitive and as a collaborative effort. Collaboration was experienced as a key and natural part of the activity. For example, some of the respondents described the experience of collaborating with others in gaming:

> *"It was fun to win a game regardless, but what was really fun was when you worked together to overcome a substantial challenge."*
>
> *"If I work with other and beat Diablo, I feel someone can share the excitement with me."*
>
> *"It's different kind of fun when playing with friends. It's like picnic with other friends vs. eating by yourself."*

Competition with others was dynamic and challenging, but since the stakes are low, in the sense that one can always start over once he/she loses the game, there is not too much pressure and thus the game could be enjoyed. For instance, respondents mentioned:

> *"The games are kind of optional, and for fun, but class is mandatory. I can quit the game at anytime, but I have to study in the classroom."*
>
> *"The game is for fun, you can lose in the game and still be happy about the experience."*

Respondent descriptions of online courses show that their experiences were highly dependent on the instructor. Instructors' course design, guidance and style, and frequency of responses to discussions influenced how students felt about the course. Additionally the sense of presence of others was an important attribute related to an online course being considered good or bad. When students received timely feedback from the instructor or peers in online discussions they appreciated and enjoyed the experience. Some sample comments are:

> *"There were always other students online at the same time to ask questions or talk about the assignment together."*
>
> *"In the discussion, like a real class discussion, we gave feedback to others and said 'yes you are right, you did good job' or 'I don't think that I agree with you, you are wrong, or you miss some points'."*

However, as expressed by our respondents, confusion, miscommunication, delay, and lack of a sense of presence are substantial aspects of the social life of online learning. Respondents indicated that they benefited from having more time to think deeper when they post their ideas. However, delays in responses, misunderstandings caused by the lack of gestures and facial expressions, and unclear text-based information tended to increase their level of frustration in online learning. Note that in table 2 the number of negative comments and the number of respondents making negative comments about the social engagement of online courses was substantially greater than the other two modes. Some examples of respondent comments are:

> *"If you don't get quality feedback it makes for a horrible online course."*
>
> *"Students cannot see the instructor, there's more chance of mis-communication than talking face-to-face. It takes much more energy for the student to make clear a question, especially when he is still at the stage of learning to ask the correct question in the course"*

Respondent descriptions of their face-to-face classes indicated that the social experience was stimulating and gratifying. The classroom atmosphere included social presence as well as pressure to perform. Respondents felt that the pressure to perform was both a bad thing and a good thing. For example, students reported:

"Since this is the face-to-face class, I can feel the learning atmosphere in the classroom. Sometimes, I might be "idle" (lost my mind) in the class; however, when feeling my peers are so eagerly joining the discussion, I will feel guilty and will get myself back right away."

"The best way for me to learn is when I have an emotion flowing through me… like happiness, sadness, embarrassed, excited. I think it is easier for that to happen in a real classroom with other people.

"I do better when I am under pressure."

In contrast, other respondents described concerns for what others might think about them:

"Sometimes I have a hard time to understand my classmates during the group discussion. People from different countries have different accents. In the group discussion, it is not polite to express that I don't understand what s/he tried to say and I am not able to have help from my instructor."

"Some times you are just not comfortable with your level of understanding compared to the whiz kids."

Role of Expert

In online games the game players experience experts as a natural part of the activity. Whether the expert is competitive or cooperative with the subject one can learn from the more experienced players:

"I like to get help when playing games, that means you can play better and go to the high levels more easily."

In online and face-to-face courses the instructor's role is critical for guidance, motivation and feedback. For example, here is a positive and a negative response related to the instructor's role in online courses:

Positive response: *"The instructor who teaches in this class usually gives feedback and grades very quickly. Immediate feedback from peers or instructors can help me shape or correct my thoughts."*

Negative response: *"The quality of the on-line course depends on how much responsibility the instructor is willing to take. On-line course is like business, if you cannot learn much from the instructor, it's a waste of money and time."*

The frequency of positive and negative responses in Table 2 for the role of the expert indicates that the role of the instructor is experienced as more problematic in online courses. One contrast that was noted between face-to-face and online instructions was that in online courses instructors are expected to be highly engaged and active during the times when students are engaged, while the instructors in face-to-face classes seemed to need only be engaged during the class time period. Another distinction was that in face-to-face classes respondents often and easily experience the instructor's enthusiasm and ability to make the course and content come to life. Students find that the face-to-face instructor can motivate them and help them stay engaged in the learning activity. Some informants described their feelings about the instructors:

"I really enjoyed going to it. The instructor used real life examples and anecdotes about what you can do with your new found engineering knowledge into the lecture. It helped engage you."

"The most attractive thing is the instructors' teaching style and attitude. I could feel the instructors' enthusiasm through his excellent lecture."

CONCLUSION

As stated in the introduction the use of online learning continues to grow, and while not presented in this paper, our respondents found task engagement benefits in online learning. However, the characterization of the social nature of online learning found in this study suggests it may miss opportunities for social learning and have hurdles for collaborative activity. In contrast, our findings show that game players experience the game as a sufficient environment for the game and that the social nature of the game is a substantial part of the game experience. The game is a custom environment well crafted to support the synchronous social experiences of collaboration and competition. One caution in interpreting our data is to keep in mind that interviews may elicit certain representations of the experience whereas observation or other approaches may highlight different aspects of the experience. For example, Steinkuehler's (2004) report about her experience of a game vividly depicts the role of an expert in socializing and apprenticing a novice player, whereas in our interviews those characterizations seem to be blended into more general terms of collaboration. Similar to the sufficiency of the social aspects of gaming, instructors in the face-to-face classroom seem able to provide a social atmosphere through personal enthusiasm and strategies to bring the content to life. Instructors in traditional settings seem well practiced and resourceful in making the topic and social context a more deeply felt experience than is provided by online text environments. The asynchronous nature of most of the online learning experiences may require new tools and strategies to support the coordination, continuity and richness experienced in games and face-to-face classes.

Our social computing research group plans to further examine the data to make sense of how the task, social context and environment are integrated into the experience of engagement. We plan to extend our data collection through additional interviews and potentially more ethnographic as well as sociological research efforts. Keeping in mind that our efforts to build a theory of action for online learning are still quite rudimentary, Strauss's (1993) guidance suggests that we need both to build explicit descriptions of action while also making sense of the broader social worlds in which those actions take place. The meanings of actions are formed in the social world and interactions generate new meanings and symbols as well as alter and maintain old ones.

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A New Method to Assess the Quality of Collaborative Process in CSCL

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Abstract: In CSCL research, the collaborative process – the way people collaborate while working on tasks and learning – is of central importance. Instructional measures are being developed to improve the quality of the collaboration which itself determines to a great extent the results of working and learning in groups. However, assessing collaborative process is not easy. We have developed a new assessment method by quantitatively rating nine qualitatively defined characteristic dimensions of collaboration. In this paper, we first describe how these dimensions were extracted from video-recordings of dyads collaborating to solve interdisciplinary tasks. Then we explain how the resulting rating system was applied to and tested on another sample. Based on positive findings from this application, we argue that the new method can be recommended for different areas of CSCL research.

Keywords: Collaborative Process, Assessment Method, Rating System, Videoconferencing, Cognitive Dimensions, Affective Dimensions

In CSCL research, the collaborative process – e.g. the way co-learners exchange information, discuss different perspectives, take on diverse roles, coordinate their efforts in solving a joint task, or make use of technological tools – is of central importance. The quality of the collaborative process determines to a great extent the results of working and learning in groups. Instructional measures are successful if they are developed based on insights about what features of the collaborative process are relevant for successful learning and problem-solving. But analyzing and assessing collaborative process is not easy, and usually very time-consuming. In this paper, a rating system is presented that can be used to evaluate the quality of the collaborative process while reviewing it on videotape, without the need of time-consuming transcription.

In the following, a short overview of methods already used in assessing collaborative process is given. We also briefly describe the instructional experiment the data of which were used in developing the new assessment method. Next, we describe the three steps that were taken in developing and evaluating the new assessment method. First, a combination of a data-driven and a theory-based approach was used to extract nine characteristic dimensions of collaborative process that were afterwards implemented in a rating system. Second, the rating system was applied to another sample and evaluated with regard to inter-rater reliability and process-outcome validity. A further approach to testing the relevance of the rating system's dimensions involved implementing them in instructional support measures and comparing the results of instructed and non-instructed dyads of collaborators.

METHODS FOR ASSESSING COLLABORATIVE PROCESS

Throughout the learning sciences, assessing and analyzing collaborative process has become a central research topic. At the International Conference of the Learning Sciences (ICLS) 2004 at Santa Monica, for example, a symposium was devoted to discussing adequate ways to record, analyze and interpret what happens during collaborative process, with the long-term goal of assembling a "methodological toolbox" (Rummel & Spada, 2004). Many researchers in CSCL agree that the process of collaboration, in addition to traditional outcome measures, should be paid closer attention (e.g. Nurmela, Palonen, Lehtinen, & Hakkarainen, 2003). Some typical methods already in use include content analysis, discourse analysis, analysis of computer-generated quantitative log files, and social network analysis (Häkkinen, Järvelä, & Mäkitalo, 2003).

Log file data, which can be automatically generated and stored by the learning environment, can serve as an easily accessible data base for analyzing collaborative process. These log file data can be used to identify activity patterns and participation structures in networked learning groups, which can also be graphically displayed (Nurmela et al., 2003). However, Nurmela et al. (2003) warn researchers not to rely primarily on the information provided by log file data (for example because one can never be sure whether an opened document is actually read), but to combine these structural analyses of the collaborative process with an analysis of its contents, especially the content of collaborative dialog.

Different coding schemes have been developed in order to label and to quantify what happens during collaborative process. One coding scheme that has been successfully employed in studies analyzing dialog from collaborative learning sessions (e.g. Kneser & Ploetzner, 2001; Pilkington & Parker-Jones, 1996) is the DISCOUNT scheme developed by Pilkington (1999). Aims of DISCOUNT include identifying dialog roles, tracking initiative and describing an episode's content structure. The system is applied in a hierarchical fashion: conversational episodes concerning a particular topic are broken down into exchanges, exchanges into turns, and turns into moves or even further into rhetorical predicates. The coding scheme provides the researcher with a large set of codes concerning the structure and function of these components. Researchers implementing the DISCOUNT scheme also use it to identify roles that learners take on. For example, Kneser and Ploetzner (2001) distinguished between the roles of information seeker, explainer, task performer and reflector. Bruhn, Gräsel, Fischer, and Mandl (1997) presented a different system of categories specifically designed to assess processes of knowledge co-construction in learners' discourse. These researchers suggest three central mechanisms of knowledge co-construction: externalization of knowledge, elicitation of knowledge, and different kinds of consensus building.

While most of the methods for analyzing collaborative process allow the researcher to quantify aspects of collaborative dialog and to identify particular interaction patterns and roles (e.g. the number of elicitations, the frequency of taking the role of a reflector, or the amount of time spent on coordination), it has been criticized that little is being said about the quality of the collaborative process (Häkkinen et al., 2003). One approach to assessing the quality more directly has been taken by Häkkinen et al. (2003) who developed a theory-based analysis method for rating the level of perspective taking in text-based online discussions, taking into account five distinct stages. Collazos, Guerrero, Pino, and Ochoa (2004) developed a set of five indicators in order to describe the interaction within groups that differed in the quality of their cooperative process and outcome. Other approaches have been completely data-driven and qualitative in nature, often following the ethnographic research tradition. These researchers (e.g. Guribye, Andreassen, & Wasson, 2003) placed their emphasis "on identifying concepts and patterns as they emerge from the data" (p. 388), for example when trying to understand which interactional processes are necessary in organizing distributed collaborative learning. In the focus of attention of Koschmann, Zemel, Conlee-Stevens, Young, Robbs and Barnhart (in press) have been sequences or patterns of actions through which group members achieve effective cooperation. For example, these authors were able to demonstrate "problematizing", i.e. a move by which participants call into doubt assumptions previously held by a group of learners. Ethnographic approaches are very helpful tools in identifying relevant aspects of the collaborative process, but usually do not provide quantitative results.

Our goal in developing a new assessment method has been to combine the benefits of data-driven as well as theory-driven approaches, and qualitative as well as quantitative methods. First, relevant dimensions of the collaborative process were extracted from the data in a qualitative procedure. Then these dimensions were implemented in a rating system that enables the user to evaluate the quality of collaborative process in a quantitative way, such that the resulting ratings can be subjected to statistical analyses.

OUR RESEARCH CONTEXT

The development of our new method for assessing the quality of collaborative process was embedded in a study on instructional support for computer-supported collaborative problem-solving given complementary expertise of the collaborating partners (Rummel & Spada, 2005). Dyads, each consisting of a medical student and a student of psychology, collaborated via a desktop video-conferencing system. Their task was to develop a diagnosis and a therapy plan for a given psychiatric case, which was carefully designed to require the combined application of both medical and psychological expertise in order to be solved correctly. The videoconferencing system allowed participants to see and hear each other while discussing the case. It included a shared workspace the students could use to prepare a written solution. The dyads were given two hours to solve the case, and their collaboration was videotaped. Prior to this testing phase, half of the dyads had undergone a learning phase in which they had been instructed on how to collaborate. The main goal of the study was to compare different methods of instructional support. As data from this study were used for developing and evaluating the new assessment instrument, a short overview of the different experimental conditions is given in Table 1.

As part of this research project we have already developed, applied and evaluated several approaches for analyzing collaborative process (Rummel & Spada, in press). A first approach was based on log-file data. We counted, for example, the minutes of individual versus joint work during problem-solving; this resulted in the finding that successful dyads showed significantly longer individual work phases. To enable a more fine-grained analysis, a number of video recordings were transcribed and the dialogs coded with regard to criteria of coordination, communication, and the topics discussed. Then the instances of particular types of coordination (e.g. minutes of talk on division of labor), of communication (e.g. turns explaining new content to the partner) and of turns with specific topics were counted. Only the analyses of the coordination revealed systematic differences between successful and unsuccessful dyads. A general problem of quantifying qualitative data by coding and counting is that the number of utterances of a particular type does not provide enough information for evaluating the quality of the collaborative process. For example, more coordinative utterances do not necessarily indicate better collaboration, because too much coordinative dialog reduces the time available for the task itself. Too many coordinative utterances might even be an indicator of failed attempts to coordinate collaboration efficiently. Therefore, we decided to develop a new method that would allow us not only to describe the collaborative process in quantitative terms, but also to assess its quality. In the remainder of this paper we will present the three steps that we have taken in the development and evaluation of this new assessment method. Table 2 gives a short overview of the data used, the methods applied, and the results obtained.

Table 1: Experimental conditions in the study by Rummel and Spada (2005) on the effects of two instructional measures on collaborative work and learning

	Learning phase	**Testing phase**
Model condition (9 dyads)	observational learning	uninstructed collaboration
Script condition (9 dyads)	scripted collaboration	
Unscripted condition (9 dyads)	uninstructed collaboration	
Control condition (9 dyads)	no learning phase	

Table 2: Data sources, methods and results in the development and evaluation of a new method to assess characteristic dimensions of collaborative process

Extracting characteristic dimensions of collaborative process and developing a rating system *Data source:* for extracting dimensions: video-recordings of the collaboration in the testing phase and transcribed dialog of 4 dyads (2 unscripted condition and 2 control condition); for developing the rating system: transcribed dialog of these 4 dyads plus 3 additional dyads (2 model condition, 1 script condition) *Method:* a thorough data-driven, qualitative analysis of the collaborative process of these dyads, combined with theoretical considerations based on the relevant literature; development of a rating system *Results:* nine dimensions of collaborative process and a rating system allowing to assess them quantitatively
Evaluating the developed rating system with regard to inter-rater reliability and validity *Data source:* video-recordings of collaborative work in the testing phase, and measures assessing the quality of the solution to the psychiatric case for 9 dyads (control condition) *Method:* applying the rating system to the collaborative process of these dyads and assessing inter-rater reliability and measures of validity by calculating process-outcome correlations *Results:* inter-rater reliability sufficient to high; high validity
Testing the relevance of the nine dimensions by implementing them in instructional support measures *Data source:* data on the quality of the solution of the case from the already reported comparison of 18 dyads with and 18 dyads without instruction (Rummel & Spada, 2005) *Method:* instructing 18 dyads on how to collaborate and comparing their outcome with that of non-instructed 18 dyads *Results:* instructed dyads produced better outcomes → the dimensions concern relevant aspects of collaborative process

EXTRACTING CHARACTERISTIC DIMENSIONS OF COLLABORATIVE PROCESS AND DEVELOPING A RATING SYSTEM

Method

In identifying relevant aspects of the collaborative process, we combined a bottom-up, data-driven and a top-down, theory-driven approach. First, in the data-driven approach, a multi-step analytical procedure built on the qualitative content analysis developed by Mayring (2003) was followed to identify process dimensions relevant for a successful collaboration (Sosa y Fink, 2003). Mayring's qualitative content analysis involves the data-driven, inductive development of categories through a stepwise reduction of transcripts, until the desired level of abstraction has been reached. In order to be able to analyze "naturally" occurring collaboration, we selected four dyads that had not received any prior instruction on how to collaborate. The collaborative dialog was transcribed. Utterances were paraphrased, generalized, and bundled into concepts according to Mayring's rules of qualitative content analysis. Higher-level concepts were formulated, and lower-level concepts subsumed. At a relatively high level of abstraction, seven categories resulted, representing characteristic features of the collaborative process. However, this set of inductively derived categories posed the problem of being not precisely enough defined and partly overlapping in content. Therefore, a complementary theory-driven approach was undertaken in order to separate them more clearly from each other, and ground them in theoretical concepts from the literature. We reviewed the literature on computer supported collaboration in order to identify aspects characteristic for successful collaboration. The focus was on dimensions of collaboration that could be directly observed from the videotaped interaction process. We neither wanted to analyze single speech acts, like in many fine-grained discourse coding schemes, nor were we looking for universal features of collaboration. Instead, we were interested in actions and interaction patterns that could be judged to be appropriate or inappropriate within the context of the given cooperative scenario. Integration of the result of the data-driven analysis with our theoretical considerations led to nine dimensions for assessing collaborative process. Finally, a rating system was developed containing a description of each of these nine dimensions, along with illustrating examples of interaction patterns and instructions on how to rate the dimensions quantitatively.

Results: Nine Dimensions of Collaborative Process and the Resulting Rating System

Successful collaboration is not possible without effective communication. In accordance with the communication theory put forward by Clark (e.g. Clark & Brennan, 1991), two important features of the communicative process are included in the rating system: *sustaining mutual understanding* (Dimension 1) and *coordinating communication* (Dimension 2). Further, collaborative problem-solving and learning can in large parts be seen as a question of information processing at the group level (Hinsz, Tindale, & Vollrath, 1997). The third and fourth dimension therefore concern processes of constructing a shared knowledge base. Two kinds of processes are distinguished, though these cannot be seen as independent: *pooling information* (Dimension 3) and *reaching consensus* (Dimension 4). Finally, collaboration can also be seen as a matter of coordination (e.g. Malone & Crowston, 1994, Barron, 2000). The focus in our rating system is on three content-unspecific aspects of coordination: *task division* (Dimension 5), *time management* (Dimension 6), and *technical coordination* (Dimension 7). In addition to these seven more cognitive oriented dimensions, two dimensions concerning motivational aspects were formulated: *shared task alignment* (Dimension 8) and *sustaining commitment* (Dimension 9). In the rest of this section, these nine dimensions are presented together with a brief glance at their theoretical background and some examples of the operationalization put forward in the rating scheme we developed. The nine categories were defined in a way to be task unspecific, i.e. they should be suitable to evaluate the quality of collaborative process for any similar task under the conditions of complementary expertise and a desktop videoconferencing setting. Table 3 gives a short overview over the resulting nine dimensions, which will subsequently be described in more detail.

Dimension 1: Sustaining mutual understanding

Sustaining mutual understanding is also known as the problem of "grounding" in communication (Clark & Brennan, 1991). Similar concepts are "convergence on central concepts", or "joint problem space" (Roschelle & Teasley, 1995). Clark and Brennan (1991) list a couple of "positive evidences" for ascertaining mutual understanding, which can be analyzed in videotaped collaboration: acknowledgements, "relevant next turns" demonstrating that the speaker has understood and is referring to what was said before, and continued attention. In a similar way the communication framework put forward by Whittaker and O'Conaill (1997) distinguishes between reference, feedback and interpersonal cues used to coordinate the content of communication. The description in our rating scheme says that for this dimension the rater should assess, among other things, whether speakers try to make their contributions understandable (e.g. by explaining technical terms), give their partners the opportunity to ask questions and elicit feedback from their partner. Both partner should listen to each other carefully, signal their continued attention and give feedback of their understanding. As a result, the collaborators' utterances should be relating to each other.

Dimension 2: Coordinating communication

Coordinating communication refers not to the content but the process of communication. This category, which is based on the "process coordination" dimension in the framework of Whittaker and O'Conaill (1997), includes processes of turn-taking and of managing the beginning and ending of conversational episodes. In videoconferencing, collaborators can facilitate turn-taking by explicitly handing over a turn, for example by naming the next speaker or posing a question (O'Conaill & Whittaker, 1997). Conversational episodes, for example between two phases of parallel individual work, should further have a clear beginning and ending. This dimension is rated depending on how smoothly the conversation is "flowing", how well the turn-taking is being managed, and whether participants try to secure their partners attention before starting a new conversational episode.

Dimension 3: Information pooling

Information pooling, especially the pooling of unshared information, is a crucial aspect of successful collaborative problem-solving (e.g. Stasser & Titus, 1985) and knowledge construction, and even more so under the condition of complementary expertise. Information pooling is mainly a matter of externalizing knowledge (Bruhn et al., 1997), but also of asking each other questions and giving explanations. Asking for as well as giving information will be more effective if both partners keep their complementary expertise in mind (as a form of metaknowledge which helps to ensure that relevant unshared information is brought into the discussion), using their partner as a resource (Dillenbourg, Baker, Blaye, & O'Malley, 1995) and also taking over the responsibility for their own domain. Finally, explanations must be given at an appropriate level of elaboration in order to be helpful (Webb, 1989). The rater should pay attention to the following aspects: Both partners should try to contribute as much information as possible, especially the distributed information. New information should be given in an elaborated way, for example illustrated through concrete examples, and be put into the context of the task at hand.

Dimension 4: Reaching consensus

Ideally, reaching consensus, e.g. concerning a decision, should be preceded by a process of critically evaluating the given information, collecting arguments for and against the options at hand and critically discussing different perspectives. This should result in socio-cognitive conflict, which is seen as very important for learning from collaboration by many authors (see for example Dillenbourg et al., 1995), and a rather "conflict-oriented" style of negotiation (Fischer & Mandl, 2002). However, as these authors point out, in computer-mediated as well as in face-to-face collaboration, participants tend to avoid conflict, trying instead to integrate their individual perspectives without really discussing them, often resulting in a "superficial conflict-avoiding cooperation style" and "an illusion of consensus". The dimension should be rated reflecting to what extent the "ideal" way of reaching consensus was followed, especially whether proposals were critically reflected by both partners, thus avoiding a superficial consensus. The point at which a final decision is made should be clearly identifiable.

Dimension 5: Task division

Task division in general involves decomposing an overall goal into subgoals and delegating the resulting subtasks to different persons (Malone & Crowston, 1994). Further, it has been shown that particularly in the case of partners with complementary expertise, there should be both joint and individual work in a well-balanced proportion (Hermann, Rummel, & Spada, 2001). On the one hand, individual phases are important so the experts can bring their individual domain knowledge to bear; on the other hand joint phases are necessary to ensure a shared understanding of the problem to be solved, and to integrate the individual work into a coherent joint solution. The rater will observe in how far the task is split into subtasks and in how far individual as well as joint phases of work and learning are distinguishable. Drafting a plan of how to divide the task and delegate the work in the beginning together with several coordinative episodes throughout the collaboration is considered ideal. Tasks should be defined and delegated according to the partners' expertise.

Dimension 6: Time management

Time management is necessary, if (as in our scenario and probably in most CSCL settings) the time available is limited. In addition to dividing the tasks at hand into several subtasks, a suitable amount of time needs to be allotted to each working phase. In our scenario we consider it to be ideal if participants take some time at the beginning of their collaboration in order to draft a schedule identifying the planned working phases. In rating this category one should pay attention to the following aspects: Each subtask should be allotted a certain amount of time which must both be short enough so the whole task can be finished in time and long enough so the work can realistically be done. Adherence to the schedule should be monitored throughout the collaborative process, for example by reminding each other of time limits.

Dimension 7: Technical coordination

In computer-mediated collaboration the aspect of technical coordination needs to be added to task division and time management. With Malone and Crowston (1994), coordination can be defined as managing interdependencies between activities. What distinguishes "good" technical coordination will always depend on the dependencies and the resources available within each specific computer-mediated collaboration setting. In our scenario, the dependency consists of the shared resources the desktop videoconference system provides. Collaborators have to coordinate their activities in a way that they do not impair each others work. For example, they have to clarify at any given time who may write into the shared text editor, which does not allow for simultaneous typing, or when to switch on and off the speakers for phases of individual work. Ideally, collaborators should make use of all the technical possibilities they have in order to facilitate their working process. All these aspects should be taken into account when rating this category.

Dimension 8: Shared task alignment

The term shared task alignment was borrowed from Barron (2000), who uses it to describe a collaborative orientation toward problem solving. Shared task alignment, as defined by Barron, refers to a certain way of coordinating the collaboration, e.g. by co-orienting actions around the task and taking up and expanding each others' contributions. Our category also comprises accepting the shared task and taking on responsibility for its solution (i.e. striving to reach a good outcome), and supporting each other during collaboration. The rater judges how readily the partners take over responsibility for their joint task, how much interest and effort they put into their work, and in how far they seem willing to support each other in this process. Showing joy and/or pride during collaboration or as result of the joint accomplishment is also seen as a positive indicator for shared task alignment.

Dimension 9: Sustaining commitment

While shared task alignment describes the basic orientation participants show toward their collaborative task, sustaining commitment aims at those processes necessary to keep up a high level of task involvement and expended effort. Above all, the collaborators' attention needs to be focused on the problem to be solved, so the problem-solving process is not impaired by competing action tendencies. There are a couple of strategies useful for the purpose of keeping up one's motivation. Collaborators can set goals they want to reach and reward themselves (and each other) for progress toward solving the problem. If the collaborators experience failures, they should focus their attention back on the task, and if they feel their own or their partner's motivation is decreasing, they should remind each other of the positive consequences solving the problem will have or formulate positive expectancies (e.g. that their combined abilities will suffice to solve the problem in a satisfying way). The occurrence of strategies like these is the basis for rating this category.

The Rating System

The resulting rating system contains a detailed description of each of the nine dimensions, along with questions intended to guide the rater's attention toward certain aspects of the collaborative process. In order to further illustrate the dimensions, the transcripts of seven dyads (among them those four used during the data-driven analysis) were searched for fitting discourse episodes. For example, the following episode was selected to illustrate how dyads can sustain mutual understanding:

> Dyad 14, Minute 04: Psychology student: "….Did you understand what I just said?" Medical student: "Uh-uh. That is, you mean, whether now there is a psychotic component in addition to the depression and the multiple sclerosis?" Psychology student: "Exactly!"

Instructions are given on how to rate each of the nine dimensions on a seven-point-scale from "very bad" to "very good". The rating is done by reviewing the video-recording of the collaborative process for each dyad. The rating sheet leaves room under each dimension so raters can take notes concerning their impression of the dyad's performance in order to aid their memory.

EVALUATING THE NEW RATING SYSTEM: INTER-RATER RELIABILITY AND PROCESS-OUTCOME VALIDITY

This paragraph describes how the instrument was applied to a sample of nine dyads in order to evaluate inter-rater reliability and the dimensions' correlations with an outcome criterion.

Method

The instrument was applied to a sample of nine dyads which collaborated freely, i.e. without prior instruction, in order to see whether the rating system was suitable to assess "natural" collaboration as it occurs in a computer-mediated setting. The sample was made up of the nine dyads in the control condition of the already mentioned experiment (Rummel & Spada, 2005; see Table 1). Transcripts of two of these dyads had already been used for the data-driven category development by Sosa y Fink (2003). All dyads were rated by two raters (A. Meier and S. Hauser); two dyads were rated jointly for training, the other seven dyads independently. To assess inter-rater reliability only the data of these seven dyads were used. Then, for all nine dyads, the ratings of the nine dimensions were correlated with an outcome criterion measuring the quality of the joint solution produced by the dyads.

Results

While working with the newly developed instrument, the raters gained the impression that the nine dimensions did indeed allow to differentiate between good and bad collaboration. All results of the statistical analyses are given in Table 4.

Table 4: Interrater-reliabilty of the 9 dimensions, their intercorrelations and the correlations with an outcome measure

Dimension	**Interrater-reliabilty** (intraclass correlation) (n = 7)	**Correlations** (Pearson, n= 9)									
		Sustaining Mutual Understanding	Coordinating Communication	Information Pooling	Reaching Consensus	Task Divison	Time Management	Technical Coordination	Shared Task Alignment	Sustaining Commitment	Quality of joint solution
(1) Sustaining Mutual Understanding	.74*	--	.43	.82*	.77*	.43	.16	.34	.78*	.55	.53
(2) Coordinating Communication	.88*		--	.08	.33	.84*	-.19	.77*	.20	.29	.60
(3) Information Pooling	.63*			--	.83*	.00	.12	.08	.69*	.39	.28
(4) Reaching Consensus	.87*				--	.35	-.14	.29	.64	.57	.30
(5) Task Divison	.84*					--	.02	.90*	.43	.64	.64
(6) Time Management	.87*						--	.11	.26	.36	.42
(7) Technical Coordination	.45							--	.52	.68*	.75*
(8) Shared Task Alignment	.70*								--	.79*	.56
(9) Sustaining Commitment	.56									--	.72*

* significant on the 0.05-level

Inter-rater agreement proved to be not perfect, but acceptable: From the seven independent ratings, intraclass coefficients (two way mixed effects model) were calculated as a measure of inter-rater reliability for each of the nine categories (see Table 4). The intraclass correlation was found to exceed .70 for all but three categories. It was highest for "coordinating communication", "reaching consensus" and "time management" and lowest for "sustaining commitment" and "technical coordination. The rating instructions for the three dimensions with an inter-rater reliability below .70 are currently being revised. For the further analyses, the mean value of the two independent ratings was calculated for each dimension. For all dyads (n = 9), correlations of the nine dimensions with each other and with an external criterion - the quality of the joint solution (i.e. the outcome of the collaboration process) - were calculated. All results are given in Table 4. Based on this small sample of nine dyads, statistical significance is only given in the case of very high correlations (r > .67). In the moment, the rating system is applied to a further and larger sample of a new experiment.

Not surprisingly, related categories inter-correlate moderately to highly. For example, high correlations were found between the two categories assessing the process of building a shared understanding of the problem, “information pooling” and “reaching consensus”, and the two categories assessing motivational aspects, “shared task alignment” and “sustaining commitment”. Summarizing these results, it can be concluded that the nine dimensions draw a rather coherent picture: Good dyads collaborate well concerning most of the dimensions.

For the quality of the joint solution (combined scores for the diagnosis and therapy parts), high correlations were found for “sustaining mutual understanding”, “coordinating communication”, “task division”, “technical coordination”, “shared task alignment”, and “sustaining commitment”. The lowest correlations were obtained for “information pooling” and “reaching consensus”. However, the processes assessed by these two dimensions were relevant for the first part of the joint solution, the diagnosis. Accordingly, they yielded higher correlations with the diagnosis score alone (r = .67* for “information pooling” and r = .52 n.s. for “reaching consensus”). Thus, the predictive validity for the outcome is moderate to high for all dimensions.

TESTING THE RELEVANCE OF THE NINE DIMENSIONS BY IMPLEMENTING THEM IN INSTRUCTIONAL SUPPORT MEASURES

Do the process characteristics that we consider to be relevant for successful cooperation actually lead to good collaborative outcomes? As we can see from the correlations between the ratings of the nine dimensions and the scores uninstructed dyads gained for their joint solution, this seems indeed to be the case. Another way of answering this question has already been taken in the experimental instructional study (Rummel & Spada, 2005). Dyads were taught to collaborate in a way which was characterized by many features resembling the dimensions of our rating system.

Method

One of the two instructed conditions in the experiment (Rummel & Spada, 2005; see Table 1) involved learning from a worked-out collaboration example (model condition). During the learning phase of the experiment, participants in this condition watched a multimedia-presentation on their computer screen. They listened to recorded scenes of the collaborative problem-solving between a psychology student and a medical student on a first psychiatric case. Animated slide-clips allowed participants to observe the development of the joint solution in the text editors of the model collaborators. An exemplary collaboration was shown in the model presentation, with many features corresponding to the characteristic dimensions of a good collaboration outlined above. Instructional explanations (such as “In the following scene you will hear how the two collaborators ask each other questions about the case. They make use of each others knowledge to clarify information given to them about the patient in the case description before they turn to the diagnosis”) as well as prompts for self-explanations were included in order to support a deeper processing of the worked-out collaboration example. The second instructional condition involved learning from scripted collaboration (script condition). Here, dyads were provided with a detailed script prescribing specific phases for their interaction. The script followed the same exemplary collaboration as presented in the model condition. The two non-instructed conditions served as controls.

Results

Results showed that both instructed conditions, model and script, outperformed the non-instructed conditions (Rummel & Spada, 2005). This implies that the dimensions represent relevant aspects of good, successful collaboration.

DISCUSSION

In this paper, we presented a new method for assessing the quality of collaborative process in computer-supported problem-solving and learning settings. Nine dimensions central to collaboration were extracted combining a data-driven analysis of collaborative process with theoretical considerations. The first two dimensions, *sustaining mutual understanding* and *coordinating communication* refer to basic communication processes which form a prerequisite for successful collaboration. The third and fourth dimension, *information pooling* and *reaching consensus*, are relevant for the construction and maintenance of a shared understanding. *Task division*, *time management* and *technical coordination* are three dimensions reflecting the coordination of collaborative activities. Finally, the motivational aspect is covered by the two dimensions *shared task alignment* and *sustaining commitment*. The rating system we developed implementing these nine dimensions enables the user to assess the quality of the collaborative process on a relatively global level, resulting in quantitative ratings that can be subjected to statistical analyses. We have shown that the inter-rater reliability of the nine dimensions is satisfactory. Rating instructions of the less satisfying dimensions are currently under revision. Some rather high inter-correlations between the dimensions indicate that maybe a leaner instrument with fewer dimensions would be sufficient.

Correlations with the quality of the joint solution are moderate to high. These process-outcome correlations, however, are not only contingent on the reliability of our process ratings but also on the reliability with which the joint outcome was assessed. Since the participants of our study had to solve complex tasks, assessing the quality of the solution was not trivial. Process and outcome measures might show an even stronger relation when applied to problems whose solution quality is easier to evaluate. Taking together all of the results, these are promising findings. Yet, a larger sample is needed to further improve the method and replicate the results.

In our approach to assessing the quality of collaborative process, we wanted to combine the benefits of qualitative, data-driven and quantitative, concept-driven approaches. We did this by first qualitatively identifying relevant dimensions of collaborative process and then implementing them in a rating system that yields quantitative ratings. Our rating system differs from quantitative methods of coding and counting (e.g. Bruhn et al., 1997, Rummel & Spada, in press), in that it affords a more holistic assessment of the quality of collaborative processes. Compared to very fine-grained discourse coding schemes, like the DISCOUNT scheme (Pilkington, 1999), which can only be applied to transcribed dialog data, the time expenditure necessary for applying our method is considerably lower. Videotaped collaboration can be reviewed without transcribing dialog. For one hour of videotaped collaboration, about two hours of time should be calculated for reviewing and rating. Raters should be trained in advance in order to be sensitive to relevant characteristics of collaborative process.

We propose that the rating system should be applicable in most areas of CSCL research that involve collaborative problem-solving and learning on the basis of complementary expertise. Of course, the rating instructions for the "technical coordination" will have to be adjusted to the specific technical setting one wishes to analyze. Although the rating system was developed and evaluated for collaboration in dyads, we think it might also be applicable to groups of three or four collaborators.

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Group Cognition: The Collaborative Locus of Agency in CSCL

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Abstract. CSCL faces the challenge of not only designing educational technologies and interventions, but of inventing analytic methodologies and theoretical frameworks appropriate to the unique character of collaborative learning as an interactional group accomplishment. This paper argues that thinking in CSCL settings should be primarily analyzed at the small-group unit of analysis, where contributions coming from individual interpretive perspectives are interwoven into group cognition. The collaborative discourse is the agent of knowledge building that requires computer support and curriculum design. Groups can think; with the help of CSCL in the next decade, they may be able to overcome the limitations of the individual mind.

Keywords: agency, shared knowledge, intersubjectivity, dialogism, group cognition, discourse, AI, emergence, Turing, Searle, Dreyfus

In the past decade, CSCL has grown willy-nilly out of various theoretical and methodological traditions that are mutually incompatible, but that each seem to contribute important insights. As is typical in exciting new fields, CSCL research has demonstrated—perhaps above all else—that relatively straight-forward extensions of traditional approaches are inadequate for addressing the intertwining issues raised by CSCL. Researchers in CSCL have come to the field from diverse disciplines and have brought with them disparate methodological traditions. If CSCL wants to become a truly international and multidisciplinary endeavor in the next decade, it needs to develop its own theoretical framework, one appropriate for defining the phenomena and methods of a unique field that transcends academic and cultural boundaries of the past.

At CSCL '03, I claimed that in situations of collaborative learning, the building of knowledge or the construction of meaning is a group process (Stahl, 2003). It produces artifacts (words, texts, pictures, tools) with group meaning. This meaning should be conceived of at the small-group unit of analysis, even though this shared meaning necessarily involves interpretation and contributions by individuals.

In this paper, I want to push this analysis further and ask, Can collaborative groups think? Answering this question in the affirmative, I want to propose a concept of group cognition (Stahl, in press). A theory of *collaborative learning as group cognition* locates the locus of agency for CSCL in the group, not in the individual, where other theories of learning seek it.

FROM AI TO CSCL

Turing (1950) famously posed the question, "Can machines think?" For the 50 years since then, the field of artificial intelligence (AI) was largely driven by the quest for computer-based (artificial) cognition (intelligence). In recent years, this quest has migrated into the development of technologies that aid or augment human intelligence. As the collaborative technologies of CSCL become more important, the trend may be even more to design computationally-intensive media to support communication among people, making their—human but computer-mediated—group efforts more intelligent.

It has become increasingly clear that computers do not "think" in anything like the way that people do. As has been repeatedly stressed in the past decade or two, human cognition is essentially situated, interpretive, perspectival and largely tacit. Computer symbol processing has none of these characteristics. Computers manipulate information that does not have meaning for the computer, but only for the people who configured or use the computer. Without meaning, there is no need or possibility to reference a situation, interpret symbols, view from a perspective or link to tacit background understanding. It is only the combination of computers with people that think in a meaningful way with the help of computer manipulation of information.

In this paper, I pose a question analogous to the classic AI question: Can groups think? In keeping with the priorities of CSCL, I am interested in the potential of small groups that are collaborating effectively with technological mediation. At CSCL ’02 I argued that collaborative knowledge building was a central phenomenon for CSCL (Stahl, 2002b), and at CSCL ’03 I extended the argument by claiming that meaning-making in collaborative contexts took place primarily at the small-group unit of analysis (Stahl, 2003). Perhaps the question of group cognition can help to set an agenda for future work in CSCL, much as Turing’s question propelled AI research in the past. Perhaps CSCL can provide a positive answer to the question, taking advantage of what AI learned in the process of arriving at its negative conclusion. After all, many technological pursuits within CSCL have been inspired by AI. In the following, we consider three important efforts to determine if computers can think, and apply their considerations to the question of whether small groups of people collaborating together can, under propitious conditions, be said to be thinking as a group. First, let us address a primary stumbling block to thinking about groups as thinking agents.

A GROUP DOES NOT HAVE A BRAIN

The common sense objection to attributing thought to small groups of people is that groups do not have something like a “group brain” the way that individual people have brains. It is assumed that cognition requires some sort of brain—as a substrate for the thinking and as an archive for the thoughts.

Thought as software. The idea of a substrate for thinking was developed in its extreme form in AI. Here, the analogy was that computer hardware was like a human brain in the sense that software runs on it the way that thinking takes place in the brain. Software and its manipulation of information was conceptualized as computations on data. Projecting this model back on psychology, the human mind was then viewed in terms of computations in the brain. Originally, this computation was assumed to be symbol manipulation (Newell & Simon, 1963), but it was later generalized to include the computation of connection values in parallel distributed processes of neural network models (Rumelhart & McClelland, 1986).

Thought as content. Thought has also traditionally been considered some kind of mental content or idea-objects (facts, propositions, beliefs) that exist in the heads of individual humans. For instance, in educational theory the application of this view to learning has been critically characterized as the pouring of content by teachers into the container heads of students (Freire, 1970). Again, this has its analogy in the computer model. Ideas are stored in heads like data is stored in computer memory. According to this model, the mind consists of a database filled with the ideas or facts that a person has learned. Such a view assumes that knowledge is a body of explicit facts. Such facts can be transferred unproblematically from one storage container to another along simple conduits of communication. This view raises apparent problems for the concept of group cognition. For instance, it is often asked when the notion of group learning is proposed, what happens to the group learning when the members of the group separate. To the extent that group members have internalized some of the group learning as individual learning, then this is preserved in the individuals’ respective heads. But the group learning as such has no head to preserve it.

Groupware as group memory. One tact to take in conceptualizing group cognition would be to argue that groupware can serve as a substrate and archival repository for group thought and ideas. Then, one could say that a small group along with its appropriate groupware, as an integrated system, can think.

Discourse as cognition. The view that will be proposed here is somewhat different, although related. We will view *discourse* as providing a substrate for group cognition. The role of groupware is a secondary one of mediating the discourse – providing a conduit that is by no means a simple transfer mechanism. Discourse consists of material things observable in the physical world, like spoken words, inscriptions on paper and bodily gestures. The cognitive ability to engage in discourse is not viewed as the possession of a large set of facts or ideas, but as the ability to skillfully use communicative resources. Among the artifacts that groups learn to use as resources are the affordances of groupware and other technologies. The substrate for a group’s skilled performance includes the individual group members, available meaningful artifacts (including groupware and other collaboration tools or media), the situation of the activity structure, the shared culture and the socio-historical context. So, in a sense, the cognitive ability of a group vanishes when the group breaks up, because it is dependent on the interactions among the members. But it is also true that it is not simply identical to the sum of the members’ individual cognitive abilities because (a) the members have different abilities individually and socially—according to Vygotsky’s (1930/1978) notion of the zone of proximal development as the difference between these—and (b) group cognitive ability is responsive to the context, which is interactively achieved in the group discourse (Garfinkel, 1967). Both of these points make sense if one conceives of the abilities of members as primarily capacities to respond to discursive settings and to take advantage of contextual resources, rather than conceiving of intelligence as a store of facts that can be expressed and used in logical inferences. To the extent that members internalize skills that have been developed in collaborative interactions or acquire cognitive artifacts that have been mediated by group activities, the members preserve the group learning and can bring it to bear on future social occasions, although it might not show up on tests administered to the individuals in isolation.

In the following, we want to explore the sense in which we can claim that small groups can think or engage in group cognition. We will successively take up the three major arguments of Turing, Searle and Dreyfus about whether computers can think, applying their considerations to group cognition.

A TURING TEST FOR GROUPS

In a visionary essay that foresaw much of the subsequent field of AI, Turing (1950) considered many of the arguments related to the question of whether machines could think. By machines, he meant digital computers. He was not arguing that the computers that he worked on at the time could think, but that it was possible to imagine computers that could think. He operationalized the determination of whether something is thinking by assessing whether it could respond to questions in a way that was indistinguishable from how a thinking person might respond. He spelled out this test in terms of an imitation game and predicted that an actual computer could win this game by the year 2000.

The original imitation game is played with three people: a man and a woman, who respond to questions, and an interrogator who cannot see the other two but can pose questions to them and receive their responses. The object of the game is for the interrogator to determine which of the responders is the woman, while the man tries to fool the interrogator and the woman answers honestly.

Turing transposed this game into a test for the question of whether computers can think, subsequently called the Turing Test:

> I believe that in about 50 years' time it will be possible to programme computers, with a storage capacity of about 10^9, to make them play the imitation game so well that an average interrogator will not have more than 70 per cent. chance of making the right identification after five minutes of questioning. (p. 442)

The test reduces the question of whether a computer can think to the question of whether a (properly programmed) computer could produce responses to a human interrogator's probing questions that could not be distinguished from the responses of a (thinking) human.

It is generally accepted that no computer passed the Turing test by the year 2000. Computer programs have been developed that do well on the test if the interrogator's questions are confined to a well-defined domain of subject matter, but not if the questions can be as wide-ranging as Turing's examples. The domain of chess is a good example of a well-defined realm of intelligent behavior. A computer did succeed in beating the best human chess player by around 2000. But interestingly, it did so by using massive numbers of look-ahead computations in a brute-force method, quite the opposite of how human masters play.

Can a group pass the Turing test? Turing argued that his test transformed the ambiguous and ill-defined question about computers thinking into a testable claim that met a variety of objections. His approach has proven to be appealing, although it is not without its critics and although it has not turned out to support his specific prediction. We will now see what we can borrow from the Turing test for the question of whether collaborative groups can think.

Suppose an interrogator communicated questions to a thinking individual person and to a collaborating small group of people. Could the group fool the interrogator into not being able to distinguish to a high probability that the group is not a person? Clearly, a simple strategy would be for the group to elect a spokesperson and let that person respond as an individual. There seems to be no question but that a group can think in the same sense as an individual human according to the Turing test.

In a sense, the Turing test, by operationalizing the phenomenon under consideration puts it in a black box. We can no longer see how thoughts (responses to the interrogator) are being produced. It is reminiscent of the limitation of many quantitative CSCL studies of learning. An operational hypothesis is either confirmed or denied, but the mechanisms of interest are systematically obscured (Stahl, 2002a). We do not really learn much about the nature of thought or learning – whether by individuals, groups or computers – by determining whether their results are indistinguishable or not. One would like to look inside the box.

A CHINESE ROOM FOR GROUPS

Searle's (1980) controversial Chinese room argument takes a look inside the box of an AI computer … and he is disappointed. Writing in an article on "Minds, Brains and Programs," Searle reviews many leading views on whether computers can think, attracts even more views in commentaries, and ends up leaving most readers in more of a quandary than when they started.

Searle's argument revolves around a thought experiment that can actually be traced back to Turing's paper. In describing a model of computers, Turing starts out by saying that a digital computer is "intended to carry out any operations which could be done by a human computer" (Turing, 1950, p. 436). By "human computer" he has in mind a person who follows a book of fixed rules without deviation, doing calculations on an unlimited supply of paper. In a digital computer, the book of rules, paper and human are replaced by software, digital memory and computer processor. Searle reverse-engineers the computer to ask if digital computers think by asking the same question of the "human computer" that Turing imagined. In his thought experiment, Searle imagines that he is the human who follows a book of fixed rules to do computations on paper.

The key move that Searle makes is to note that the computer follows the rules of its software *without* interpreting them. To get a feel of the computer's perspective on this, Searle specifies that the symbols coming into the computer and those going out are all in Chinese. As Searle (who knows no Chinese) sits inside the computer manipulating these symbols according to his book of rules in English, he has no idea what these symbols mean. The software that he executes was cleverly programmed by someone who understood Chinese, so the outputs make Chinese sense as responses to their inputs, even though Searle who is manipulating them inside the computer has no understanding of this sense. From the outside, the computer seems to be behaving intelligently with Chinese symbols. But this is a result of the intelligence of the programmer, not of the human computer (Searle) who is blindly but systematically manipulating the symbols according to the program of his rule book in English.

According to Searle's thought experiment, a computer could, for instance, even pass the Turing test without engaging in any thoughtful understanding whatsoever. Human programmers would have written software based on their understandings, human AI workers would have structured large databases according to their understandings and human interrogators or observers would have interpreted inputs and outputs according to their understandings. The computer would have manipulated bits following strict rules, but with no understanding. The bits might as well be in an unknown foreign language.

Searle's reformulation of the question is whether the instantiation of some AI software could ever, by itself, be a sufficient condition of understanding. He concludes that it could not. He argues that it could not because the computer manipulations have no *intentionality*, that is they do not index any meaning. If a sequence of symbols being processed by the computer is supposed to represent a hamburger in a story about a restaurant, the computer has no understanding that those symbols reference a hamburger, and so the computer cannot be described as intelligently understanding the story. The software programmer and the people interacting with the computer might understand the symbols as representing something meaningful, but the computer does not. Searle distinguishes the perspective of the computer from that of its users, and attributes understanding of the processed information only to the users. He says of machines including digital computers that "they have a level of description at which we can describe them as taking information in at one end, transforming it and producing information as output. But in this case it is up to outside observers to interpret the input and output as information in the ordinary sense" (Searle, 1980, p. 423).

Searle concludes that there is necessarily a material basis for understanding, that no purely formal model like a software program can ever have. He says that he is able to understand English and have other forms of intentionality

> because I am a certain sort of organism with a certain biological (i.e., chemical and physical) structure, and this structure, under certain conditions, is causally capable of producing perception, action, understanding, learning and other intentional phenomena. And part of the point of the present argument is that only something that had those causal powers could have that intentionality. (p. 422)

For Searle, "intentionality" is defined as a feature of mental states such as beliefs or desires, by which they are directed at or are about objects and states of affairs in the world.

Putting Searle into a group. Searle is quite convinced that computers cannot think in the sense proposed by strong AI advocates. Do his arguments apply to groups thinking?

Applying Searle's thought experiment, analysis and conclusions to the question of whether a collaborative group could think is tricky because of the shift of locus of agency from a single physical object to a group of multiple objects, or subjects. What would it mean to remove the individual Searle from his hypothesized computer and to put him into a collaborative group? It would make no sense to put him into a Chinese-speaking group. But we are not asking if every possible group can be said to think, understand or have intentional states. Can it be said of *any* collaborative group that it thinks? So we would put Searle into a group of his English-speaking peers. If the group started to have a successful knowledge-building discourse, we can assume that from Searle's insider position he might well agree that he had an understanding of what was being discussed and also that the group understood the topic.

Would he have to attribute understanding of the topic to the group as a whole or only to its members? If the utterances of the members only made sense as part of the group discourse, or if members of the group only learned by means of the group interactions, then one would be inclined to attribute sense-making and learning to the group unit. This would be the attribution of intentional states to the group in the sense that the group is making sense of something and learning about something—i.e., the group is intending or attending to something.

Another move that Searle considers with his human computer experiment is to have the person who is following the rules in the book and writing on scraps of paper then internalize the book and papers so that the whole system is in the person. In Searle's critique of Turing, this changes nothing of consequence. If we make a similar move with the group, what happens? If one person internalizes the perspectives and utterances of everyone in a collaborative group, that person can play out the group interactions by himself. This is what theoreticians of dialog—e.g., Bakhtin (1986) and Mead (1934/1962)—say happens when we are influenced by others. Vygotsky (1930/1978) sees this process of internalization of social partners and groups as fundamental to individual learning. When one plays out a debate on a topic by oneself, one can certainly be said to be thinking. So why not say that a group that carries out an identical debate, conceivably using the same utterances, is also thinking?

The only issue that still arises is that of agency. One might insist on asking *who* is doing the thinking, and be looking for a unitary physical agent. The group itself could be spread around the world, interacting asynchronously through email. Perhaps a collaboration takes place over time such that at no one time are all the members simultaneously involved. Where is the biological basis for intentionality, with its causal powers that Searle claims as a necessary condition for intentionality, understanding and thought? Certainly, one would say that thought went into formulating the individual emails. That can be explained as the result of an individual's biology, causality, intentionality, understanding, etc. But, in addition, the larger email interchange can be a process of shared meaning-making, where the meaning is understood by the group itself. Comments in a given email may only make sense in relation to other emails by other members.

The group may rely on the eyes of individuals to see things in the physical world and it may rely on the arms of individuals to move things around in the physical world, because the group as a whole has no eyes or arms other than those of its members. But the group itself can make group meaning through its own group discourse. The interplay of words and gestures, their inferences and implications, their connotations and references, their indexing of their situation and their mediating of available artifacts can take place at the group unit of analysis. These actions may not be attributable to any individual unit—or at least may be more simply understood at the group level.

BEING-IN-THE-WORLD AS GROUPS

The third "critique of artificial reason" that we want to consider is that of Dreyfus (1972; 1986; 1991). Dreyfus agrees with Searle that AI has emerged from the attempt to push a specific philosophic position too far, to the detriment and confusion of AI. Dreyfus calls this extreme position "representationalism" and argues that it ignores much of what accounts for human understanding. It in effect reduces our complex engagement in the world, our sophisticated social know-how and our subtle sense of what is going on around our embodied presence to a large database of symbols and books of explicit rules:

> Rationalists such as Descartes and Leibniz thought of the mind as defined by its capacity to form representations of all domains of activity. These representations were taken to be theories of the domains in question, the idea being that representing the fixed, context-free features of a domain and the principles governing their interaction explains the domain's intelligibility … mirrored in the mind in propositional form. (Dreyfus, 1992, p. xvii)

Representationalism reduces all knowing, meaning, understanding, cognition, intelligence to the possession of sets of facts, ideas or propositions. It matters little whether these explicit formulations of knowledge are said to exist in an ideal world of non-material forms (Plato), as purely mental thoughts (Descartes), as linguistic propositions (early Wittgenstein) or stored in database entries (AI). Wittgenstein's early *Tractatus*, which reduces philosophy to a set of numbered propositions, begins by defining the world as "the totality of facts, not of things" (Wittgenstein, 1921/1974, § 1.1). From here, via the work of the logical positivists, it is easy to conceive of capturing human knowledge in a database of explicit representations of facts—such as Searle imagined in his books of programmed instructions for manipulating Chinese symbols.

The problem with representationalism, according to Dreyfus, is that it ignores the diverse ways in which people know. The consequence that Dreyfus draws for AI is that it cannot succeed in its goal of reproducing intelligence using just formal representations of knowledge. Dreyfus highlights three problems that arose for AI in pursuing this approach: (1) sensible retrieval, (2) representation of skills and (3) identification of relevance.

Retrieval. The AI approach has proven unable to structure its knowledge-bases in a way that supports the drawing of commonsensical inferences from them. For instance, as people learn more about a topic, they are able to infer other things about that topic faster and easier, but as a computer stores more facts on a topic its retrieval and inference algorithms slow down dramatically.

Dreyfus details his critique by focusing on a large AI effort to capture people's everyday background knowledge and to retrieve relevant facts needed for making common sense inferences. Dreyfus argues that the logic of this approach is precisely backward from the way people's minds work:

> The conviction that people *are* storing context-free facts and using meta-rules to cut down the search space is precisely the dubious rationalist assumption in question. It must be tested by looking at the phenomenology of everyday know-how. Such an account is worked out by Heidegger and his followers such as Merleau-Ponty and the anthropologist Pierre Bourdieu. They find that what counts as the facts depends on our everyday skills. (Dreyfus, 1992, p. xxii)

Skills. AI representations cannot capture the forms of knowledge that consist in skills, know-how and expertise. People know how to do many things—like ride a bike, enjoy a poem or respond to a chess position—that they are unable to state or explain in sentences and rules. The effort within AI to program expert systems, for instance, largely failed because it proved impossible to solicit the knowledge of domain experts. An important form of this issue is that human understanding relies heavily upon a vast background knowledge that allows people to make sense of propositional knowledge. This background knowledge builds upon our extensive life experience, which is not reducible to sets of stored facts.

> Human beings who have had vast experience in the natural and social world have a direct sense of how things are done and what to expect. Our global familiarity thus enables us to respond to what is relevant and ignore what is irrelevant without planning based on purpose-free representations of context-free facts. (p. xxix)

Relevance. A fundamental interpretive skill of people is knowing what is relevant within a given situation and perspective. This sense of relevance cannot be programmed into a computer using explicit rules. This ability to focus on what is relevant is related to people's skill in drawing inferences and builds on their expert background knowledge.

> The point is that a manager's expertise, and expertise in general, consists in being able to respond to the relevant facts. A computer can help by supplying more facts than the manager could possibly remember, but only experience enables the manager to see the current state of affairs as a specific situation and to see what is relevant. That expert know-how cannot be put into the computer by adding more facts, since the issue is which is the current correct perspective from which to determine which facts are relevant. (p. xlii)

Dreyfus emphasizes that *facts* are not what is immediately given in human experience and understanding. Rather, what is to count as a fact is itself mediated by our skills, our situation in the world and our perspective as embodied and engaged.

Dreyfus' critique shows that computers cannot think in the most important ways that people do. Arguing on the basis of a Heideggerian analysis of human being-in-the-world as situated, engaged, perspectival, skilled and involved with meaningful artifacts, Dreyfus provides the basis for understanding the failure of computers to pass the Turing test and to exhibit the kind of intentionality that Searle argues is a necessary condition of cognition. Explicit, propositional, factual knowledge is not an adequate starting point for analyzing or duplicating human cognition. There are a number of factors that come first analytically and experientially: tacit know-how, practical skills, social practices, cultural habits, embodied orientation, engaged perspective, involvement with artifacts, social interaction, perception of meaningfulness and directedness toward things in the world. Heidegger's (1927/1996) analysis of human existence, for instance, begins with our being involved in the world within situational networks of significant artifacts. Our relationship to things as objects of explicit propositions and our expression of factual propositions are much later, secondary products of mediations built on top of the more primordial phenomena. Similarly, Merleau-Ponty (1945/2002) stresses our orientation within a meaningful social and physical space structured around our sense of being embodied. Because AI representations lack the features that are primary in human cognition and try to reduce everything to a secondary phenomenon of factual propositions, they ultimately fail to be able to either imitate human cognition to the degree envisioned by Turing or to capture the sense of understanding sought by Searle.

Being-with-others in groups. We now turn to the question of whether the proposed notion of group cognition fares any better against these standards than did the AI notion of computer cognition.

Clearly, the individual members of a group bring with them the skills, background and intentionality to allow a group to determine what are the relevant facts and issues. But in what sense does the group as a whole have or share these? We do not define the group as a physical collection of the members' bodies. The group might exist in an online, virtual form, physically distributed across arbitrary spatial and temporal distances. Rather, the group exists as a discourse, perhaps recorded in a video, chat log or transcript. This group discourse can reflect such tacit skills, commonsense background knowledge and intentionality.

Group discourse is engaged in a group activity, embedded within a context of tacitly understood goals and situated in a network of meaningful artifacts. The discourse itself exhibits intentionality. It builds upon tacit background knowledge of the experiential world. It adopts—sometimes through involved group processes of negotiation and enactment—perspectives that determine relevance. So groups can think in much the same situated, engaged way that individuals do.

GROUP DISCOURSE AS EMERGENT THINKING

This paper has argued that small collaborative groups—at least on occasion and under properly conducive conditions—can think. It is not only possible, but also quite reasonable to speak of groups as engaging in human cognition in a sense that is not appropriate for applying to computer computations, even in AI simulations of intelligent behavior. When we talk of groups thinking, we are referring not so much to the physical assemblage of people as to the group discourse in which they engage.

To some social scientists, such as Vygotsky, the group level (which he calls social or inter-subjective) is actually prior in conceptual and developmental importance to the individual (intra-subjective) level. So why does the notion of group cognition strike many people as counter-intuitive? When it is recognized, it is generally trivialized as some kind of mysterious "synergy." Often, people focus on the dangers identified by social psychologists as "group think"—where group obedience overrides individual rationality. At best, the commonsensical attitude acknowledges that "two heads are better than one." This standard expression suggests part of the problem: thought is conceived as something that takes place inside of individual heads, so that group cognition is conceived as a sum of facts from individual heads, rather than as a positive cognitive phenomenon of its own.

An alternative conceptualization is to view group cognition as an *emergent* quality of the interaction of individual cognitive processes. The emergence of group cognition is different from other forms of emergence. Conversation is the interaction of utterances, gestures, etc. from a small number of people. The interaction can be extremely complex. It involves the ways in which subsequent utterances respond to previous ones and anticipate or solicit future ones. Individual terms carry with them extensive histories of connotations and implications. Features of the situation and of its constituent artifacts are indexed in manifold ways. Syntactic structures weave together meanings and implications. Effective interpretations are active at many levels, constructing an accounting of the conversation itself even as it enacts its locutionary, perlocutionary and illocutionary force (Searle, 1969).

Yes, small groups can think. Their group cognition emerges in their group discourse. This is a unique form of emergence. It differs from statistical, simple-rule-governed and social emergence. It is driven by linguistic mechanisms. Understanding group cognition will require a new science with methods that differ from the traditions of AI, psychology and educational research—methods based on the interactional subtleties of conversational discourse rather than on statistical regularities.

GROUP COGNITION AND CSCL

Many methodologies popular in CSCL research focus on the individual as the unit of analysis and locus of agency: what the individual student does or says or learns. Even from the perspective of an interest in group cognition and group discourse, such methods can be useful and provide part of the analysis, because group thinking and activity is intimately intertwined with that of the individual members of the group. However, it is also important and insightful to view collaborative activities as linguistic, cognitive and interactional processes at the group level of description. This involves taking the group as the unit of analysis and as the focal agent. One can then analyze how a group solves a problem through the interplay of utterances proposing, challenging, questioning, correcting, negotiating and confirming emergent group meaning. One can see how a group does things with words that have the force of accomplishing changes in the shared social world. Some things, like electing an official, can only be done by groups—although this obviously involves individuals. Other things, like solving a challenging problem, may be done better by groups than by individuals—although the different perspectives and considerations are contributed by individuals.

CSCL is distinguished as a field of inquiry by its focus on group collaboration in learning; it makes sense to orient the methods of the field to thinking at the small-group unit of analysis. This may require re-thinking—as a research community—our theoretical framework, such as our conceptualization of "cognition" that we have inherited from the representationalism of cognitive sciences and learning sciences oriented overwhelmingly toward the individual.

Group interactions may be characterized as "cognitive" because they display the requisite characteristics of sequentiality, accountability and sense making—not because they are extensions of individual cognition. Group cognition is a phenomenon at the small-group unit of analysis, not a derivative of either individual thinking or community-level establishment of cultural resources. It is the source of knowledge constructed collaboratively—and is therefore an appropriate foundation for CSCL.

Individual learning enters the picture secondarily. Because collaboration requires shared understanding, processes of group cognition generally ensure that all participants keep pace with the group, to the extent needed for the group discourse's practical purposes. This causes individuals to develop and alter their interpretations of constructed meaning and perhaps internalize cognitive artifacts based on the products of group cognition, such as meaningful texts.

The exploration of empirical case studies of small-group knowledge-building discourse are needed to help to describe in both concrete and theoretical ways how group cognition is accomplished as a linguistic achievement. Rigorous conversational analysis of multiple studies will lead to an improved understanding of the methods that participants use to constitute and structure group interaction and to engage in collaborative problem solving.

THE NEXT DECADE

The Internet offers the potential to join individual minds together effectively across time and space, thereby overcoming the limitations of individual cognition. Networked computers not only allow global access to information, but could also facilitate collaborative knowledge building within online communities. However, numerous case studies in CSCL have found that even in virtual environments intentionally designed to support knowledge building, discussions are generally limited at best to the sharing of personal opinions. Commercial systems provide media for generic communication or transmission of information, but no specific support for the phases of more involved collaboration. Driven by the market-place demands of corporate users and educational institutions, the designs of these systems aim to structure and control individual access and usage rather than to scaffold group cognition.

We need to better conceptualize collaborative knowledge building as a set of group processes. This will lead to the analysis of group cognition as a phenomenon of small-group discourse. Contributions to collaborative knowledge-building discussions do not typically express meanings that already existed in mental representations of individual participants. The utterances are indexical, elliptical and projective in the sense that they contribute to meaning at the group unit of analysis by virtue of their embeddedness in the group situation, discourse and activity. The meaning and the knowledge are originally constructed through group cognition. Individual cognition may later result from internalization or retrospective accounts. Accordingly, evidence of collaborative learning is to be found in the brief episodes of shared meaning making in which group knowing is constituted, rather than in traces of lasting capabilities of individuals, which are subject to numerous psychological factors.

In particular, conversation analysis (Psathas, 1995; Sacks, 1992) can serve as a methodology for making group cognition visible. Methodologically rigorous interpretations (Koschmann, Stahl, & Zemel, 2005) can analyze intersubjective interactions like turn-taking, knowledge negotiation, adjacency pairs and conversational repair. Through such analysis, we can see that the basic components of collaborative knowledge building are not actions of individuals, but are methods of small-group activity. Through them, shared meanings are proposed, adopted and refined. The processes of group cognition incorporate contributions by individuals, based on individual interpretations of the emerging and evolving group meanings. But these individual utterances are essentially fragmentary; they only become meaningful by virtue of their contributing to the group context. That is why computer support for collaborative knowledge building must be centrally concerned with group cognition.

The cycle of software prototyping, conversation analysis and theoretical reflection must be iterated repeatedly. Many innovations of CSCL systems will have to be developed and tried out, building a whole field of technology for use in supporting specific group methods of collaboration. The interactions that take place online in these and other contexts must be analyzed systematically, in order to catalog methods that people use to accomplish their group work, learning, communicating and thinking. The technology and the analyses should be conceptualized within a vocabulary adequate for making sense of them. A theory of group cognition may provide a starting point for this.

The comprehension of how thinking takes place at the small-group locus of agency will guide the design of more effective computer support for collaborative knowledge building. Then the potential of group cognition can blossom around the world. This will require a global effort, itself a major instance of group cognition. This defines the task of CSCL in the next decade.

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How Can We Use Hypervideo Design Projects to Construct Knowledge in University Courses?

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Abstract. In this paper a course concept based on collaborative construction of hypervideos is presented. The course concept integrates a) hypervideo technology development, b) research on learning with hypervideo systems, and c) the application of research on knowledge acquisition by writing texts or hypertexts to hypervideos. We demonstrate how collaborative construction of hypervideo can support knowledge transforming processes (see Bereiter & Scardamalia, 1987; Stahl & Bromme, 2004) in university courses of psychology students. In the first part of the paper a hypervideo system that enables collaborative design activities by users is discussed. Afterwards the course concept is presented in detail. Evaluation results are consistent with our assumptions. The course concept showed to be successful and well appreciated by the students.

Keywords: Collaborative hypervideo design, knowledge transforming, hypervideo.

INTRODUCTION

Hypervideo is defined as *video based hypermedia* that combines non-linear information structuring and dynamic audio-visual information presentations (videos presenting realistic images or animations). In hypervideos, video information is linked with different kinds of additional information (like written or spoken texts, pictures, or further videos). Users can mouse-click on *sensitive regions* within the videos to access the additional information (see figure 1). One main difference between sensitive regions in a hypervideo and links in a hypertext is that the sensitive regions have spatial and temporal characteristics. This allows highlighting a specific object or person within the video for a predefined timeframe. The main difference between videos in traditional hypertexts and hypervideos lies in the importance attributed to the video itself. In hypertexts videos are often illustrative and optional. In hypervideos, video sequences form the "backbone of the system" (Zahn, Schwan & Barquero, 2002). Thus, videos and the additional information elements are interwoven in ways that videos can be viewed interactively and navigated in non-linear order.

Defining hypervideo-links in a video sequence enables an author to refer to a specific object / person within the video by providing additional information. We have extended this concept by developing a cooperative hypervideo system that supports the collaborative authoring of hypervideo systems where group members can share their ideas (Zahn & Finke, 2003). The system provides specific facilities to jointly elaborate on video materials and to change a hypervideo presentation according to the development of knowledge present in *any* group. In this sense hypervideo can be defined as *dynamic information space (DIS)*, which can be changed and extended as a basis to share knowledge and to communicate. The dynamic information space integrates interactive videos, additional information and communication.

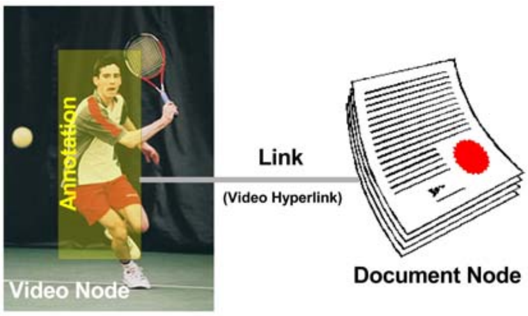

Figure 1: Concept of hypervideo

Our human computer interface concept is based on a view model. The model allocates separate views within the graphical user interface to access certain parts of the dynamic information space in form of the different node types within the DIS: V*ideo nodes* are video sequences with sensitive regions which are presented in the video view. The existence of a sensitive region is announced by its visualization within the video display. Since it might be disturbing in some learning situations, the user is in charge to initialize the visualization process of sensitive regions. Hypervideo-links can be activated by clicking on the corresponding sensitive region with a mouse pointer. Furthermore, the video view allows users to generate own sensitive regions. *Additional information* are presented in a separate view and can be of different media types like texts, images, animations, audio recordings, etc. It is possible to link multiple nodes with additional information to one sensitive region within our system. *Communication nodes* describe the conversation between users and are therefore highly contextualized. The communication view presents the group conversation in form of text based dialogs (chat). A dialog is always related to an object in the video or to a specific information node. In addition, a fourth view is introduced that enables the disclosure of the *hypervideo-structure* in order to support user orientation within the graphical user interface. The arrangement of all node types within the structure is visualized in a text-based manner. Users can browse the navigation view and activate hypervideo-links, which will lead to the presentation of the content in the associated views.

These facilities, in turn, can be utilized in formal educational contexts such as projects at university, as will be described in the following paragraphs.

COLLABORATIVE HYPERVIDEO DESIGN

During the last years a growing number of courses in hypermedia production have been offered in schools and universities that focus on students' collaborative design of multimedia. It can be assumed form the constructivist perspective of situated cognition (e.g. Jacobson & Spiro, 1995) that such courses allow to create a learning context, which incorporates important features to foster deeper understanding and knowledge transfer: Students have to solve the realistic and authentic problem of how to present a topic within their hypermedia in an appropriate way. They are engaged in an active and constructive process of learning, and because of the complexity of the task, that can only be solved in collaboration, they are challenged to articulate and negotiate meaning with their fellow students.

However, the production of hypermedia is a highly complex task: It is not easy to maintain the balance between thinking about the content to be processed and thinking about design features of hypermedia (Dillon, 2002). Accordingly, problems that arise in such projects include that either too much attention is paid to the design of hypermedia while the contents are only included with 'copy & paste' (Bereiter, 2002). Or that students present the contents in a way that is inappropriate for the format of hypermedia. A consequence of both cases is that students develop a superficial comprehension of the subject matter presented by their products. Therefore it seems necessary to find an appropriate balance to encourage reflection on the contents on the one hand and reflection about the hypervideo design on the other. This assumption is made in analogy to ideas from research on writing traditional text and hypertext. Concerning text production, Bereiter and Scardamalia (1987) propose that writing can only contribute to knowledge acquisition when a text is formulated within a continuous interaction between content-related knowledge (on the topic addressed in the text) and rhetorical knowledge (on the design of the text, the anticipated audience, the genre, etc.). This problem-oriented procedure (called knowledge transforming) requires authors to reflect on and extend their own knowledge about the topic. Concerning hypertext writing, Stahl and Bromme (2004) used the knowledge-transforming model as a heuristic to examine conditions and processes of learning by constructing hypertexts and to develop a course program for university courses, respectively. They argued that constructing hypertexts places special constraints on the design of the documents through the features of hypertext, the nodes, the links and the multi-linear structure. As they described in detail, the processes of writing nodes, selecting appropriate links, planning the overall structure and flexible ways of reading might result in deeper knowledge about the concepts within a subject matter, a deeper comprehension of semantic structures within the subject matter and to a more flexible use of this new knowledge.

In designing hypervideos, the rhetorical and design knowledge that can be acquired by learners is even more broadly defined than it is with writing hypertext (Zahn, Schwan, & Barquero, 2002). It is additionally important to consider which symbol system is appropriate for which kind of information, which information should be presented as dynamic information in the videos and which is better suited to be presented as static information in additional text nodes. Further on, the new link type of sensitive regions within videos determines new kinds of decisions about the setting of links and the design of an overall hypervideo structure. We assume that these reflections should contribute to an appropriate situational model of the contents to be processed (in sense of Kintsch, 1998). And this, in turn, should help students to understand the respective topic more deeply and to be able use it more flexible in transfer situations.

We ran a series of regular university courses about "*learning with new media"* at the University of Muenster, Germany to examine whether the complex task of designing hypervideos could be managed by the students and to test, which instructional help the students needed. These courses will be described in more detail in the next paragraphs.

HYPERVIDEO DESIGN IN REGULAR UNIVERSITY COURSES

The courses in hypervideo design are part of the psychology masters program (diploma) at the University of Muenster. They are offered as courses on e-learning. 10 to 16 students participate in each course. The topics of the hypervideos produced within the courses were ‘techniques of presentation and moderation’ in the first course and a parallel course at the University of Linz, Austria (lectured by Stephan Schwan), ‘information system about study of psychology at the University of Muenster’ in the second course, and ‘conflict management’ in the third course (this course is still running). The hypervideos have to be designed from scratch, i.e. students have to plan all the video materials and the additional information, to write storyboards and text nodes, to film and to edit the videos and to integrate the different video and additional nodes in a coherent hypervideo structure. A screenshot of one of the students’ hypervideos is shown in figure 2.

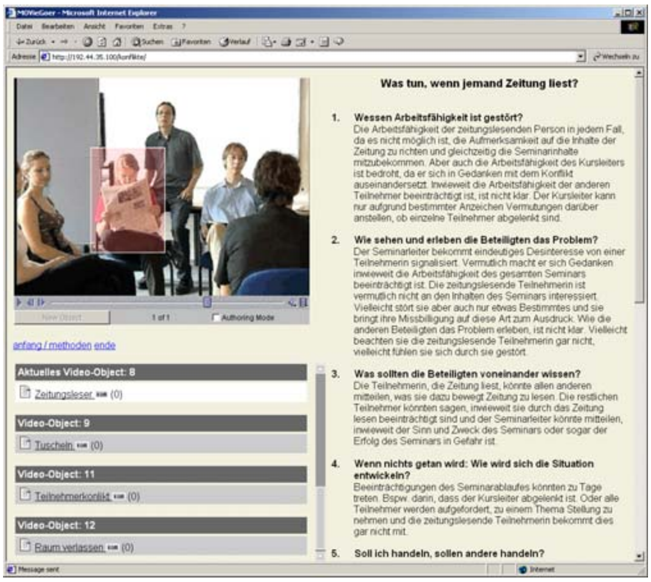

Figure 2: Hypervideo about ‚techniques of moderation’

As a heuristic to structure our (second and third) courses of hypervideo design we relied on the course program for hypertext writing developed by Stahl and Bromme (2004), which is based on results from their studies on writing hypertext in secondary schools and several experiments on knowledge acquisition by writing hypertext (e.g. Bromme & Stahl, 2002, 2005, Stahl, 2001). The program of Stahl & Bromme (2004) consists of five instructional units to teach university students how to use the features of hypertext consciously. Each unit covers one aspect, which have to be dealt with during writing hypertext:

1. Unit: Developing a basic understanding of hypervideo design. First of all, students have to understand what hypervideos are. Knowledge about texts and genres is important for text comprehension (e.g. Hayes, 1996) and text production (e.g. Kellogg, 1994). For the new medium ‘hypervideo’ students have no schemas about such regularities, and might rely on more familiar – but inappropriate - media formats. To familiarize students with the idea of hypervideos, we shot a ‘concept map video’ that visualized the planning phases of the video nodes and the additional material (see figure 3). This video enabled students to plan, produce and revise their materials using the hypervideo system from the very beginning of their design work. Further on, a possibility for discussions was embedded in the concept map videos with help of the integrated chat-tool explained above. Students were able to comment and discuss their ideas, exposés and storyboards within the hypervideo system (figure 3). The possibility to work with the hypervideo software from the very beginning substantially enhanced students understanding of hypervideo. They developed a concrete mental model of their own hypervideo, and the materials could be successively exchanged with further versions, until the hypervideo was ready.

2. Unit: Producing video nodes and text nodes with additional information. Secondly, students have to decide which contents they want to include in their hypervideo and to design the video and additional nodes. The important issue that students have to decide is: Which symbol system is appropriate for which kind of information? With help of the ‘concept map video’ (figure 3) we asked students’ to plan the video nodes and the additional material within a series of three steps: They had to develop main ideas, exposes and storyboards for the videos before we allowed them to shoot the films. Parallel to this they were asked to develop their ideas, exposes and concrete nodes for the additional material. For the additional material we asked the students to consider two general principals that we adapted from node design within hypermedia (e.g. Gerdes, 1997): Each node should only contain the necessary amount of information that refers directly to the specific video content. Further on, each text node must be comprehensible without reading further nodes. We asked students to design their additional material with these principles in mind.

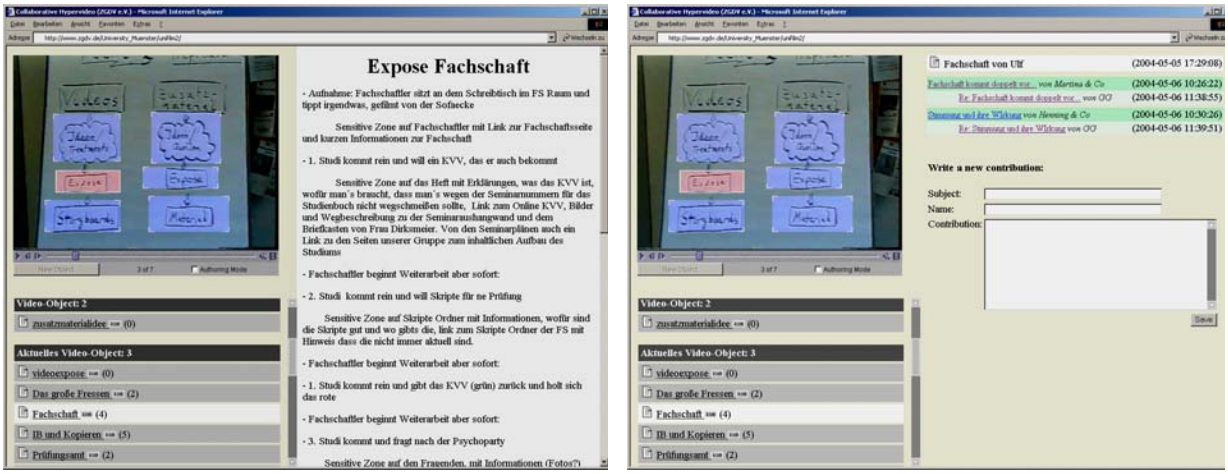

Figure 3: Concept map video: Left side: Students are able to integrate their ideas, exposes and videos from the beginning; right side: An embedded chat-tool enables them to discuss and review their material

3. Unit: Organizing an overall structure of the hypervideo. During the third unit, Stahl and Bromme (2004) asked their students to discuss the macrostructure (in sense of Kintsch, 1998) of the contents. Thus, the aim of this unit is to foster students' comprehension of the semantic structure. To design an overall structure for their hypervideos students had to plan the structure of each of these single hypervideos (one video and the relevant additional information) and how to structure all single hypervideos within an overall hypervideo. To plan the single hypervideos mainly refers to plan how to link the information within the videos with the relevant additional material and to decide, if references to other videos should be included. For planning the overall structure we asked the students to construct a concept map presenting the relations between all single hypervideos and the nodes with additional material.

4. Unit: Considering multiple perspectives in the hypervideos. During the fourth unit, the students are asked to consider different user perspectives and to present multiple ways of navigation. This idea is based on Cognitive Flexibility Theory (CFT, see, e.g. Jacobson & Spiro, 1995). CFT deals with how knowledge about a complex ("ill-structured") domain can be acquired in a way that ensures its flexible use. The goal is to stimulate learning transfer and to avoid 'inert knowledge', that is, knowledge a learner can reproduce, but fails to apply in new situations (Bereiter & Scardamalia, 1987). If authors are asked to take different user perspectives into account, knowledge might be acquired in a way that supports its flexible application. Concerning hypervideo design multiple perspectives can be included on different levels. First of all, it is possible to communicate perspectives through the videos, e.g. in a hypervideo about communication strategies it might be useful to present the same scene from different camera perspectives or to show parallel videos that differ in some aspects. In the cooperative hypervideo system it is also possible to link different additional information to one sensitive region in the video. Therefore it is possible to interpret the same scene in a video from different perspectives. On the level of the overall structure that connects all single hypervideos (see unit 3) students can plan different guided tours or different structural overviews for audiences with different perspectives. Therefore, hypervideo offers many possibilities to reflect about and include multiple perspectives.

5. Unit: Planning and setting of sensitive regions and links. During the fifth unit, students are asked to discuss the sensitive regions to be placed in their hypervideos and the links within the additional information units. Links have two important and closely related functions: they enable the user to navigate within the hypertext and they represent the semantic relations between the node contents. Therefore the selection of offered links has a great influence on navigation (e.g. Wright, 1993) and on comprehension of the contents (e.g. Gray, 1995). Consequently, we assume that linking nodes is a sensitive task that should result in a deeper processing of the information content. We try to enhance the awareness and comprehension of semantic relations by asking our students to justify each link that they want to set. Students have to discuss, which kind of semantic relation they want to express by a link, and why this relation might be important in the context of this particular node.

It is important to note that each unit might result in revisions of the material developed so far. Therefore the process of hypervideo design should be seen as a circular process, even if the units are arranged in an instructional sequence.

EVALUATION OF THE COURSES

Up to know we have little empirical evidence about the effects of the instructional units on knowledge acquisition by hypervideo design. Stahl & Bromme (2004) had developed the units as a result of their studies in six different school classes, their series of five experiments about effects of different instructions on hypertext writing and their own courses on hypertext writing with university students. Therefore it is reasonable to assume that the course design might be beneficial to support knowledge transformation in courses on hypervideo design as well.

Nevertheless we were able to run short evaluations of the courses by analyzing the design process and the products together with the students using interviews, questionnaires and group discussions. Comparing the first courses (in Münster and Linz) with the second course gave first confirmations of our assumptions. We had used the instructional program only during the second course. In the first courses the students had more freedom to decide for themselves how to organize their work. We found strong differences in the products of these courses that confirmed the appropriateness of the instructional units. The hypervideos of the first two courses included 5 hypervideos and 16 additional texts (Linz) and 8 hypervideos with 37 additional texts and 2 additional videos (Münster). The hypervideo of the second course was significantly larger with 14 hypervideos, 9 additional videos and 195 additional texts. Further on, the hypervideos of the second course included - on average - significantly more sensitive regions then those of the first courses, $F(1, 27) = 4.13$, $p = .05$ (first courses: $M = 3.85$, $SD = 2.12$; second courses: $M = 6.67$, $SD = 4.38$). The approximate time of the hypervideos in the second course was on average significantly shorter than in the first courses, $F(1, 27) = 25.05$, $p < .01$ (first courses: $M = 301.39$ sec., $SD = 87.71$; second courses: $M = 143.71$ sec., $SD = 75.92$). Qualitative analyses of the hypervideos confirmed these differences. The hypervideos of the students in Linz looked like instructional films. All relevant information was given in the videos and all additional information seemed unimportant to understand the videos. In the first course in Münster it was the opposite way around. In half of the videos all relevant contents were given in the additional information and the hypervideos themselves seemed unimportant. In contrast, the product of the second course looked like a real “hyper-“video.

It seemed that the students within the first courses were not able to develop an appropriate idea of hypervideos: They compared hypervideos either with traditional instructional films or with traditional hypertext. This resulted in planning activities which focused either too much on the videos, or the main focus was given to the additional material (see unit 1). This also led to significantly longer videos (unit 2) and less links between videos and additional information (unit 5). Further on, the hypervideos of the first course were “stand-alone” videos compared to the hypervideos of the second course that were integrated in an overall structure (unit 3) with multiple possibilities to navigate though the information space (unit 4).

The group discussion and the interviews with the students of the first course also revealed that they differed in their opinion about the learning outcome about the topic and the design of learning environments. From these results and our observations during the courses it seems doubtable that the anticipated knowledge transforming processes occurred. In contrast it can be concluded from interviews with the students of the second course, their products and a special designed questionnaire, that they gained substantial experiences with the design of learning environments and complex project work. They also gained a deeper understanding about the topics to be presented. To give an example, students of the second course completed a questionnaire with different items concerning their judgments of knowledge acquisition in the course. Each item had to be rated on a 5-point scale from 1 = ‘I completely disagree’ to 5 = ‘I completely agree’. Students assessed that the collaborative design of hypervideo fostered their active knowledge acquisition about the topic to be presented ($M = 4.28$, $SD = 1.11$), their knowledge about designing learning environments ($M = 4.71$, $SD = 0.49$), and their knowledge about cooperative project work ($M = 4.85$, $SD = 0.38$). They also rated the quality of their hypervideo on a German spectrum of school notes (with 1 = very good to 5 = insufficient) as ‘very good’ ($M = 1.29$, $SD = 0.48$). We further presented their hypervideo to another course on learning with new media ($n = 16$) that was not involved in the design process. The students rated the quality of the hypervideo as ‘good’ ($M = 2.00$, $SD = 0.73$). From such results and the informal feedback of the students, we might conclude that the anticipated knowledge transforming processes occurred. These results of the evaluations can only be seen as first hints, but they support our assumptions about the necessity of a didactical concept like our instructional program.

CONCLUSION

We can conclude that it is possible to integrate the complex task of hypervideo design into regular university courses. But it seems highly important to structure the task for the students. The knowledge transforming model gives a useful recognition of the need for balance in orienting learners to focus on the hypervideo design and learning contents of the hypervideo. We used the five units of the instructional program from Stahl and Bromme to teach the students gradually how to deal with the features of hypervideo. It was no problem to adopt it to the specific demands of hypervideos.

Nevertheless, the experiences within the courses should only be seen as a starting point for experimental research on the affordances and benefits of learning with hypervideos. A lot of open questions appeared. Thus, concerning future perspectives, the experiences within these field studies will be used to conduct a series of controlled experiments to investigate selected aspects of collaborative hypervideo design in laboratory learning settings.

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Functional versus Spontaneous Roles during CSCL

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Abstract. In this paper, two studies are reported on the effect of functional roles on computer-supported collaborative learning (CSCL) in higher education – the second is a replication of the first. Prescribed functional roles were implemented in half of all groups during a project-based course in higher education. All communication was via e-mail. Analysis of Likert-scale evaluation questionnaires gathered in both studies revealed a latent variable 'perceived group efficiency' (PGE) which – depending on the level of constraints set by preconditions – appears to increase the awareness (Study 1) or the level of efficiency (Study 2). However, Likert-scales provide a surface level analysis of actual behaviour and no insight in the collaborative process. Hence, the e-mail communication was investigated with two content analysis procedures: content analysis of the type of communicative statements and analysis of the role behaviours performed in role and nonrole groups. Results from both studies reveal that significantly more statements are focused on coordination in role groups. In addition, analysis of role behaviour reveals that students in role groups perform significantly more according to the functional roles than their counterparts in nonrole groups, although spontaneous role behaviour emerged in nonrole groups as well.

Keywords: roles, coordination, collaboration, computer-mediated communication, triangulation

INTRODUCTION

Computer-Supported Collaborative Learning (CSCL) is a relatively new discipline in the field of educational technology. At present, there are no clear guidelines to determine how a CSCL environment should be designed (Strijbos, Kirschner, & Martens, 2004a). To a considerable extent this is caused by differences in group size, the technology used, the length of the study, the research methodology and the unit of analysis (Lipponen, 2001). The design of CSCL environments often seems based on subjective decisions regarding tasks, pedagogy and technology, or general views regarding pedagogical support such as cooperative learning or collaborative learning. At present, it is increasingly acknowledged that 'learning' and 'collaboration' rely on interaction (Baker, 2002; Stahl, 2004; Strijbos, Martens, & Jochems, 2004b) and thus that *group interaction* is the primary process to be studied to assess performance and learning benefits in CSCL environments.

Group performance effectiveness depends on the one hand on the groups' use of their alternate opinions and on the other hand on the handling of increased coordination (Shaw, 1981). Conflicts regarding coordination are likely to occur in asynchronous CSCL settings (Benbunan-Fich & Hiltz, 1999). Group cohesion and a sense of responsibility can affect coordination. Responsibility is proportionally related to group performance (i.e., a greater sense of responsibility can increase group performance). Group cohesion has been shown to increase stability, satisfaction and efficient communication (Forsyth, 1999). Group cohesion and responsibility correspond with two key concepts in collaborative learning: 'positive interdependence' and 'individual accountability'. Roles can be used to foster these key concepts, and subsequently promote group cohesion and responsibility (Mudrack & Farrell, 1995). Roles are defined as more or less stated functions/duties or responsibilities that guide individual behaviour and regulate intra-group interaction (Hare, 1994). In addition, roles can stimulate awareness of the overall group performance and each members' contribution (Mudrack & Farrell, 1995). Finally, roles appear to be most relevant when a group pursues a shared goal requiring a certain level of task division, coordination and integration of individual activities.

Several pedagogical approaches that have been developed for cooperative learning use roles to support coordination and intra-group interaction (Johnson, Johnson, & Johnson-Holubec, 1992; Kagan, 1994). These roles are either content-oriented or process-oriented. Content-oriented roles focus on the facilitation of knowledge acquisition, using for example 'scripted cooperation' (O'Donnell & Dansereau, 1992; Weinberger, 2003). Process-oriented or management roles focus on individual responsibilities regarding the coordination (e.g., Kynigos, 1999). These role descriptions share, however, that they comprise one single job, task or duty. Collaboration assignments in higher education are more complex and take place over an extended period of time (i.e., not restricted to classroom time), thus requiring more explicit coordination. Consequently, the previous mentioned uni-dimensional roles for face-to-face collaboration appear inadequate to support collaboration in higher education, let alone asynchronous CSCL settings.

INVESTIGATING THE EFFECT OF FUNCTIONAL ROLES

Both studies reported in this paper investigate the impact functional roles, which are based on role descriptions by Johnson et al. (1992), Kagan (1994), and Mudrack and Farrell (1995). The roles were designed to give each student an individual responsibility, but at the same time all roles were essential to the collaboration and thus interdependent (project planner, communicator, editor and data collector; for a detailed description see Strijbos, Martens, Jochems, & Broers, 2004c). The research question in both studies was: 'What is the effect of a prescribed functional roles instruction, compared to no instruction, on group performance and collaboration?'.

In one previous study (Strijbos, et al., 2004c) principal axis factoring of several 5-point Likert-scales (i.e., team development, group process satisfaction, task strategy and the level of intra-group conflict) and a single question rated on a 10-point scale (the quality of collaboration) from the evaluation questionnaire revealed a latent variable (explaining 79% of all common variance) that was interpreted as 'perceived group efficiency' (PGE). Multilevel modelling (MLM) of PGE yielded a positive marginal effect revealing that functional roles appear to increase students' *awareness* of perceived group efficiency. This study is hereafter referred to as Study 1. The second study is a replication of the first (Strijbos, Martens, Jochems, & Broers, in press-a), as examination of the course design in the first study identified several preconditions that – if controlled – could ensure a more evenly matched comparison of the research conditions (i.e., preference for a practice assignment, slow or fast study pace, setting up of a time schedule, establishing a communication discipline and externalising expectations regarding effort). Analysis of the Likert-scales revealed again the latent variable PGE (explaining 71% of all common variance) and MLM showed that the functional roles appeared to increase the *level* of perceived group efficiency. This study is hereafter referred to as Study 2.

Most questionnaires – especially Likert-scales – provide a surface level analysis of actual behaviour. The perception of collaboration gives no insight in the actual collaborative process. It is possible for instance that role groups and nonrole groups in Study 1 were equally active in organising and coordinating their activities, hence no difference regarding PGE level could be found. Similarly, the difference between role groups with a high and low PGE level might have been caused by more 'rigid' role behaviour (i.e., strictly performing the task belonging to the assigned role). In addition, research shows that role behaviour emerges spontaneously to some extent (De Laat & Lally, 2003). Hence, it is imperative that the communication is subjected to analysis to determine *why* a group perceives themselves as more efficient and to explore *how* students coordinate and organise their collaboration.

A quantitative content analysis approach was taken. Since the communication is coded, summarised and frequencies or percentages are used for comparisons and statistical testing, such an approach requires more rigour to warrant the apparent robustness of conclusions. Lack of reliability increases the probability of Type II errors (wrongly accepting the null-hypothesis) and to a smaller degree, Type I errors (wrongly rejecting) can occur. Moreover, examples of statistical comparison without intercoder reliability appear in CSCL reports (Pata & Sarapuu, 2003). To conduct the research that is reported in this paper, two content analyses procedures were constructed. Although the research context was similar, the unit of analysis was different. One procedure investigated the type of communicative statements and a segmentation procedure was developed (see Strijbos, Martens, Prins, & Jochems, in press-b). The other procedure was designed to investigate role behaviour and a message was used as the unit of analysis. Data on the reliability of the procedures will be provided in the results section of Study 1.

STUDY 1

At the Open University of the Netherlands (OUNL), 57 students enrolled in a course on 'policy development' (PD) and 23 in a course on 'local government' (LG). In total 80 students enrolled. Five students enrolled in both courses making a total of 75 participants (45 male and 30 female; age 23-67 years, Mean = 34.4, SD = 9.03) and 43 completed the course successfully (53.8 %). The design was a quasi-experimental random independent groups design. Four functional roles were introduced in half of the groups (distributed by the members amongst themselves), aimed at promoting coordination and organisation of activities essential for the group project: project planner, communicator, editor and data collector (see Strijbos et al., 2004c). The other half of the groups received a non-directive instruction (e.g., obvious, unspecific and general information regarding planning and task division) and the students were told to rely on their intuition and/or collaboration experiences (see Strijbos et al., 2004c). Each group consisted of four students and during the course they communicated electronically via e-mail. Their task was to collaboratively write a policy report regarding reorganisation of local administration.

Prior to collaboration a face-to-face meeting was organised (separate for each condition). All groups were required to inform the supervisor whether they started with the practice assignment or immediately with the final assignment that would be graded. Role groups were required to inform their supervisor about the assignment of the roles in their group within two weeks and hand-in a progress report every two weeks. Supervisors were instructed to focus on the content of the assignment. If a request for process support was received, students in the role condition were told to rely on the roles, whereas students in the nonrole condition were told to rely on their intuition or experiences with collaboration. It is by no means possible or feasible to exclude customary communication channels (e.g., telephone or face-to-face). If used, students were requested to send transcripts to their group members to retain transparency of communication. In spite of geographical distance three groups organised a face-to-face meeting. Five students participated in both courses and were placed in the same research condition (none of these students finished both courses). If only two members remained, that group was excluded from the analyses.

Content analysis of communication

To analyse the communicative statements a 'sentence or part of a compound sentence that can be regarded as a meaningful sentence in itself, regardless of coding categories' was used as the unit of analysis (Strijbos et al., in press-b). Intercoder reliability of two trials was .82 and .89 (proportion agreement). This was corroborated by a cross-validation check on an English language set of discussion forum messages during project-based learning (high similarity to the research context) where proportion agreement was .87. In addition, a coding scheme was constructed with five main categories, and reliability (Cohen's kappa) proved to be on average .70 (substantial, cf. Landis & Koch, 1977):

- Task coordination (TC): any statement that concerns the alignment of intra-group collaboration through references with respect to time, references with respect to an activity (that is to be or has been) performed by a group member or the group, or a reference to time and an activity (e.g., "Who makes an inventory of pressure groups that are involved?");
- Task content (TN): any statement that is aimed at the content of the task or assignment in general, statements focusing on the problem solving or discussion of task content, and/or focusing on the content or editing of the report (e.g., "We should delete section two.");
- Task social (TS): any statement that contains a qualitative judgment, an evaluation or attitude towards collaboration in general, towards the whole group or specifically towards (the effort by) an individual group member (e.g., "Maarten, my compliments for your analysis.");
- Non task (NT): any statement regarding previous experiences, face-to-face meetings, acquaintance, technical problems, and social affairs not directed towards the task, or that expresses to contact the moderator (e.g., "How was your holiday?");
- Non-codable (NOC): any statement that cannot be assigned any of the other codes previously described (e.g., "Attached a new schedule with the latest deadlines and tasks.").

Content analysis was performed on all e-mail messages contributed by forty students equally distributed across both research conditions (role and nonrole; n = 5 and N = 20). Statistical comparisons were restricted to the number of messages, segments and the frequency for each main category on the level of the group. Because of the small number of observations, a Mann-Whitney U-test was performed to compare research conditions (five groups in each condition). All communication on the first assignment that a group performed (practice or final) was analysed. It was expected that roles would decrease the amount of coordinative statements in favour of content focused statements. Results are depicted in Table 1.

	Role (n = 5)			*Nonrole* (n = 5)		
Item	M	SD	*Rank*	M	SD	*Rank*
Number of messages	78.20	22.30	7.2	52.40	17.47	3.8
Number of segments	759.60	173.04	7.8	401.20	156.12	3.2
Task coordination	63.95	16.99	7.2	37.35	20.45	3.8
Task content	37.65	17.22	7.4	16.35	16.48	3.6
Task social	4.40	2.73	7.5	1.95	0.48	3.5
Non task	21.40	7.76	7.1	12.55	4.83	3.9
Non-codable	62.55	13.73	8.0	32.10	10.33	3.0

Table 1. Mean, standard deviations and Mann-Whitney rank scores for the number of messages, number of segments and the five main categories.

No main effect was observed for the amount of messages send, but a significant difference was observed for the amount of segments (U = 1.000, df = 4, p < .05). Regarding the content of the communication several main effects were observed in favour of the role condition: significant more 'task coordination' (U = 4.000, df = 4, p < .10), 'task content' (U = 3.000, df = 4, p < .05), 'task social' (U = 2.500, df = 4, p < .05), and 'non-codable' statements (U = 0.000, df = 4, p < .05) were made in the role condition.

Content analysis of role behaviour

A procedure was developed to investigate the communication to what extent students acted according to their functional roles, as well as whether spontaneous roles emerged in the nonrole groups. A 'message' was the best suited unit of analysis given our research objectives (Strijbos et al., in press-b). Each task belonging to one of the four functional roles was re-worked into a coding category. These were aggregated in five main categories: one for each role and a 'no code' category. Role behaviour is less frequent than communicative statements and it was decided to summarise the behaviour at the level of the message, i.e. the number of times that role behaviour was performed in a single e-mail was not taken into account. Each e-mail was assigned one of five codes:

- Project planner (P): statements about data, activities and deadlines and statements that remind other group members of their activities, as well as delegating an activity to a fellow group member, setting-up a discussion agenda and stimulating discussion around the information sources (e.g., "When all have responded, Lisette can setup a planning.");
- Communicator (C): statements that concern communication with the supervisor, as well as informing the supervisor about the groups' progress and asking questions on behalf of group members and communicating the answers (e.g., "I will send a message to our supervisor about our progress.");
- Editor (E): statements that concern writing a first draft of the group report and any subsequent versions, each of them followed by a request for comments and suggestions by all other group members (e.g., "I have written a first draft of the report; please send you comments as soon as possible.");
- Data collector (D): statements regarding the pre-selection of relevant information (data) sources provided on a Cd-rom, as well as statements concerning the collection of alternative information sources, and distributing them amongst other team members (e.g., "I have found some relevant sources on the Cd-rom.");
- Non-code (NC): no code assigned to an e-mail message.

The proportion of agreement was 81% and Cohen's kappa was .67, which is substantial (cf. Landis & Koch, 1977). Case summaries were made for each group (Table 3). Role behaviour is indicated by the capitals P, C, E and D. Members of the role groups are represented according to their role (Pp, Co, Ed and Dc). Nonrole group members are represented by their initials. It should be noted, that students in nonrole groups were less likely to exert C-behaviour as they were not required to hand in a progress report. However, the role descriptions were guiding and not coercive, so it is likely that even students in role groups performed other behaviours than those specified by their role. Since group members in nonrole groups *could* have performed a role, but were *by no means expected* to do so, an analysis of concordance is unsuited as it neglects the possibility of role behaviour by chance. To correct for chance Cohen's Kappa was computed (Table 2). Since any member of a nonrole group could have performed a role, nonrole kappa's are based on the distribution with the most possible scores on the diagonal. In addition, the total amount of role behaviour was computed for each group.

	Role	
Group	Total behaviour	Kappa
PD 1	49	.41
PD 2	62	.40
PD 3	63	.22
PD 4	116	.31
LG 1	65	.02
	Nonrole	
Group	Total behaviour	Kappa
PD 5	75	.00
PD 6	23	.09
PD 7	53	.03
LG 2	32	.14
LG 3	54	.11

Table 2. Total amount of role behaviour and consistent role behaviour (Cohen's kappa) per group.

No main effect was observed for the total amount of role behaviours aggregated at the group level (Mean Rank_{role} = 6.80; Mean $\text{Rank}_{nonrole}$ = 4.20; U = 6.000, df = 4). A directional Mann-Whitney U-test revealed a significant difference between the research conditions with respect to the extent that – functional or spontaneous – roles were performed (U = 4.000, df = 4, p < .05; one-sided). These results indicate that group members in role groups predominantly perform the tasks (role behaviour) that are expected. Table 2 reveals that the role groups with the highest (PD 2) and lowest (PD 1) level of perceived group efficiency (PGE) (Strijbos et al., 2004c) did not differ in their kappa value, illustrating that role groups with a low PGE level did not act more rigidly according to the functional roles than those with a high PGE level. The kappa values for nonrole groups are consistently low or very low and the slightly higher values for LG 2 and LG 3 indicate that roles may have emerged spontaneously. Table 3 illustrates that students in role groups performed predominantly according the functional roles (bold scores on the diagonal) and also that 'role behaviour' emerged spontaneously to some extent in nonrole groups, i.e. a project planner in LG 2 (Gr) and an editor in LG 3 (Ve).

Role						*Nonrole*					
PD 1						PD 5					
	P	C	E	D	Σ		P	C	E	D	Σ
Pp	**19**	1	0	1	21	Re	**20**	1	**14**	1	36
Co	12	**3**	0	1	16	Ve	**9**	0	**4**	0	13
Ed	4	0	**7**	0	11	Ni	**9**	0	**5**	1	15
Dc	4	1	0	**6**	11	Vd	**8**	0	**3**	0	11
PD 2						PD 6					
	P	C	E	D	Σ		P	C	E	D	Σ
Pp	**19**	0	1	4	24	Wi	**5**	0	**4**	0	9
Co	3	**8**	3	3	17	Jo	**4**	0	**2**	0	6
Ed	7	0	**9**	3	19	Bo	**4**	1	**5**	0	10
Dc	2	0	0	0	2	St	**1**	0	**2**	1	4
PD 3						PD 7					
	P	C	E	D	Σ		P	C	E	D	Σ
Pp	**17**	0	6	3	26	Mo	**20**	1	**4**	1	26
Co	12	**3**	3	0	18	Kn	**4**	0	**0**	0	4
Ed	4	0	**7**	0	11	Ro	**10**	0	**4**	1	15
Dc	2	0	4	**2**	8	Ka	**7**	0	**1**	0	8
PD 4						LG 2					
	P	C	E	D	Σ		P	C	E	D	Σ
Pp	**8**	0	6	1	15	Gr	**8**	1	**2**	0	11
Co	31	**19**	8	2	60	Va	**7**	1	**2**	0	10
Ed	7	0	**16**	3	26	Ap	**3**	0	**4**	0	7
Dc	2	0	2	**11**	15	Te	**4**	0	**0**	0	4
LG 1						LG 3					
	P	C	E	D	Σ		P	C	E	D	Σ
Pp	**8**	0	5	1	14	Ho	**7**	0	**4**	1	12
Co	4	**0**	1	0	5	Jh	**4**	0	**3**	0	7
Ed	8	2	**8**	2	20	Ve	**10**	1	**13**	2	26
Dc	11	1	12	**2**	26	Bk	**3**	0	**4**	2	9

Table 3. Case summaries of role behaviour per individual, group and condition.

It is also apparent, however, that whether a student in a nonrole group assumed a specific role s/he still performed other role behaviours, predominantly P and E behaviours. Moreover, the E-behaviour in the nonrole groups is mostly spread across all members (bold scores), whereas in role groups this behaviour is more bound to a single member exerting the specific functional role. This same pattern can also be identified to some extent with the P-behaviour (bold scores).

STUDY 2

At the Open University of the Netherlands (OUNL), 39 students enrolled in a course on 'policy development' (PD) and 25 in a course on 'local government' (LG). In total 64 students enrolled. Five students enrolled in both courses making a total of 59 participants (32 male and 27 female; Age 22-55 years, Mean = 38, SD = 8.42, 1 missing) and 49 completed the course successfully (76.5 %). The design was similar to Study 1: functional roles were introduced in half of the groups and their task was to construct a shared policy report regarding reorganisation of local administration. All communication was through e-mail. Based on the evaluation of the first study students were asked to indicate, prior to the course, whether they wanted to start with a practice assignment or proceed immediately with the final assignment that would be graded. They were also asked whether they preferred a slow (ten months) or fast (six months) study pace. Most students could be grouped according to their preference; however, given the number of registering students it was not always possible to maintain groups of four students. In contrast to the first study, however, nonrole groups had to hand in a progress report every four weeks as well: on the one hand to increase a 'sense' of supervision but on the other hand to retain a difference with the role groups (progress report every two weeks). Overall, three groups in the role condition were composed of three members from the start. A separate role instruction was provided for these groups in which the tasks of the data collector were added to the editor. It was assumed that this did not increase the students' workload as the instruction explicitly stated that studying the data could be distributed. The other four groups started with four members. In the nonrole condition, two groups started with five members and the other four groups with four members. Five students participated in both courses and they were placed in the same research condition (three students in the role condition and two in the nonrole condition). Two students that participate in both courses at the same time had to be grouped in the same condition and group (one of them dropped out in both groups due to a conflict with the other group member). Four students already participated in either course in the previous year and were placed in the same condition (three students in the role condition and one in the nonrole condition). None of these students were grouped in the same group. Although some students participated in both courses and/or for a consecutive time, they were included in the analyses because efficiency and collaboration relies on the intra-group interaction with all other group members and they collaborated with three other students with whom they had not worked before. If only two members remained, that group was excluded from the analyses.

Content analysis of communication

The analysis methodology was similar to Study 1. Content analysis was performed on all e-mail messages contributed by fifty-one students equally distributed across both research conditions (role n = 7, N = 25; nonrole n = 6 and N = 26). All communication on the first assignment that the group performed (practice or final) was analysed. One nonrole group started with the practice assignment, but half way this group switched to the final assignment, yet it was decided to include only the communication on the practice assignment in the analysis. Including all communication would not only result in an increase of statements coded, but specifically coordination would be over represented as this is typically conducted in the first half of the collaboration. Initially it was expected that roles would decrease the amount of coordinative statements, however based on the Strijbos et al. (2004c) results, the expectation for the second study was adjusted to an increase of coordination. A Mann-Whitney U-test was performed to compare both conditions. Results are depicted in Table 4. A main effect was observed for the number of messages sent ($U = 7.000$, $df = 5$, $p < .05$), however, no difference was observed for the number of segments coded. Significant more 'task coordination' ($U = 9.000$, $df = 5$, $p < .05$; one-sided) was observed in favour of the role groups. No main effect was found for the other main categories.

	Role (n = 7)			*Nonrole* (n = 6)		
Item	M	SD	*Rank*	M	SD	*Rank*
Number of messages	128.57	29.27	9.0	80.29	41.14	4.7
Number of segments	1053.71	348.62	7.1	1059.17	526.13	6.8
Task coordination	114.96	46.06	8.7	75.73	32.98	5.0
Task content	61.90	41.90	6.6	65.82	52.97	7.5
Task social	9.63	5.25	8.6	5.20	4.82	5.2
Non task	26.68	14.52	7.4	21.99	8.09	6.6
Non-codable	92.60	48.36	7.4	81.92	53.16	6.5

Table 4. Mean, standard deviations and Mann-Whitney rank scores for the number of messages, number of segments and the five main categories.

Content analysis of role behaviour

Case summaries were made for each group (Table 6). Role behaviour is indicated by the capitals P, C, E and D, the members of the role groups are represented according to their role (Pp, Co, Ed and Dc) and nonrole group members by their initials. Similar to Study 1, the role behaviour distribution was investigated by computing a Cohen's kappa for each matrix – using the scores on the diagonal as the indicator for functional role behaviour. In contrast to Study 1, the students in nonrole groups now handed in a progress report every four weeks: still retaining a difference with students in role groups who handed in a report every two weeks. Nevertheless, compared to Study 1 students in nonrole groups are more likely to exert C-behaviour (and the role descriptions were still guiding and not very coercive).

Whereas all groups in Study 1 formed a perfect four by four matrix, the analyses in Study 2 were more complicated. Three role groups performed according to three roles and thus the behaviours in the E-column represents the combined total of E and D behaviour. This does not favour the role groups because D-behaviours are generally distributed across all members and thus this aggregation leads to more deviations from the diagonal than scores on the diagonal. In addition, two nonrole groups consisted of five group members. Similar to Study 1 the kappa in nonrole groups is based on the distribution with the most possible scores on the diagonal because any member could have performed a role consistently. In addition, the group member that in any combination caused the highest number of deviations from the diagonal was eliminated. In other words, similar to Study 1 the most optimal four by four matrices – in terms of functional roles – were created for the nonrole groups. Table 5 present the total amount of role behaviour for each group and the obtained kappa values.

	Role	
Group	Total behaviour	Kappa
PD 1	72	.35
PD 2	64	.32
PD 3	131	.09
PD 4	95	.20
PD 5	103	.10
LG 2	95	.41
LG 4	115	.17
	Nonrole	
Group	Total behaviour	Kappa
PD 6	67	.09
PD 7	66	.14
PD 8	45	.07
PD 9	108	.09
LG 1	42	.23
LG 3	77	.10

Table 5. Total amount of role behaviour and consistent role behaviour (Cohen's kappa) per group.

In contrast to Study 1, a significant main effect was observed for the amount of role behaviour aggregated at the group level (U = 9.000, df = 5, p < .05; one-sided). Students in role groups performed more role behaviours than students in nonrole groups. A directional Mann-Whitney U-test showed a significant difference between the research conditions with respect to the extent that – functional or spontaneous – roles were performed (U = 7.500, df = 5, p < .05; one-sided). Similar to Study 1 the results indicate that – in general – group members in role groups perform functional role behaviour that is expected. Table 5 reveals that the role groups with the highest (PD 4) and lowest (PD 2) level of perceived group efficiency (PGE) do differ slightly in their kappa value. However, PD 2 is the only role group in the second study with a low PGE level and compared to the other groups with a high PGE level (see Strijbos et al., in press-a) the kappa obtained for PD 2 does not indicate that this group acted more rigidly according to the functional roles. In Table 5 also a high kappa value can be observed for PD 3, but a low PGE level was observed, signalling that role behaviour does not automatically lead to a higher PGE level. The kappa values for nonrole groups are low or very low, but compared to Study 1 a little higher, apparently because the nonrole groups were required to hand in progress reports as well. The slightly higher values for PD 7 and LG 1 indicate that roles may have emerged spontaneously.

Table 6 illustrates that students in role groups acted predominantly according to the functional roles (bold scores on the diagonal) and that role behaviour emerged spontaneously to some extent in nonrole groups, i.e. a project planner emerged in LG 1 (Vo) and PD 9 (Sc), an editor emerged in PD 7 (Wa), and in PD 6 (Ev), LG 1 (Mo) and LG 3 (We) a communicator emerged. It is apparent that students with an emergent role in a nonrole group still perform various other role behaviours. Finally, similar to Study 1, E-behaviour – and to some extent also P-behaviour (bold scores) – is spread predominantly across all nonrole members (bold scores), whereas in role groups this behaviour is on average bound to the member exerting the specific functional role.

Role							*Nonrole*					
PD 1							PD 6					
	P	C	E		Σ			P	C	E	D	Σ
Pp	**13**	0	7		20		Mc	**18**	2	**7**	1	28
Co	11	**7**	5		23		Ev	**6**	4	**3**	0	13
Ed	8	0	**21**		29		Ne	**13**	2	**6**	0	21
							Db	**5**	0	**0**	0	5
PD 2							PD 7					
	P	C	E	D	Σ			P	C	E	D	Σ
Pp	**18**	1	3	0	22		Re	**13**	3	**1**	0	17
Co	6	**4**	1	1	12		Vk	**13**	2	**2**	1	18
Ed	8	1	**9**	1	19		Wa	**14**	2	**8**	2	26
Dc	7	0	1	**3**	11		Sw	**3**	0	**1**	1	5
PD 3							PD 8					
	P	C	E		Σ			P	C	E	D	Σ
Pp	**28**	0	12		40		Ra	**14**	0	***0***	0	14
Co	28	**11**	11		50		Th	**10**	1	***0***	0	11
Ed	30	0	**11**		41		Le	**5**	0	***0***	0	5
							Vg	**13**	1	***0***	1	15
PD 4							PD 9					
	P	C	E		Σ			P	C	E	D	Σ
Pp	**36**	0	8		44		Sc	**29**	6	**4**	2	41
Co	15	**7**	3		25		Vb	**10**	0	**7**	0	17
Ed	18	1	**7**		26		Me	**7**	3	**10**	3	23
							Vl	**19**	1	**6**	1	27
PD 5							LG 1					
	P	C	E	D	Σ			P	C	E	D	Σ
Pp	**15**	5	8	1	29		Vo	**8**	1	**1**	0	10
Co	4	**1**	2	0	9		Mo	**5**	4	**2**	0	11
Ed	21	2	**21**	2	46		Va	**5**	2	**4**	1	12
Dc	9	0	7	**3**	19		Ev	**5**	1	**2**	1	9
LG 2							LG 3					
	P	C	E	D	Σ			P	C	E	D	Σ
Pp	**27**	0	4	3	34		Gr	**17**	0	**4**	0	21
Co	7	**7**	0	4	18		We	**15**	4	**2**	0	21
Ed	11	0	**16**	1	28		Ma	**16**	2	**6**	0	24
Dc	9	0	0	**6**	15		We	**8**	0	**3**	0	11
LG 4												
	P	C	E	D	Σ							
Pp	**18**	0	8	0	26							
Co	5	**5**	0	0	10							
Ed	28	4	**21**	1	54							
Dc	15	1	6	**3**	25							

Table 6. Case summaries of role behaviour per individual, group and condition.

DISCUSSION

In this paper the impact of functional roles, adapted for a computer-mediated context in a higher and distance education setting, was investigated with two content analysis procedures. Previous reported results from two studies focused on grades and Likert-scale questionnaires, which tend to provide a surface level analysis of actual behaviour. Hence, all e-mail communication was subjected to two content analysis procedures.

In Study 1 content analysis of the communication shows – as hypothesised – more 'task content' statements in the role condition. However, this was not due to a decrease in the amount of coordinative statements. In fact, the amount of coordinative statements increased, which disproves the alternative interpretation for the lack of significant difference between research conditions regarding PGE, i.e. that the groups in both conditions were equally active in coordinating their collaboration. Apparently, the roles stimulated coordination and as a result 'task content' statements increased as well. Content analyses with respect to 'role behaviour', functional or spontaneous, revealed qualitative differences between role and nonrole groups regarding the collaboration process. No difference was observed in the total amount of role behaviour, but group members of role groups performed role behaviours, associated with their functional role, more frequently than members with a different functional role. The kappa values for nonrole groups are consistently low or very low and the slightly higher values for LG 2 and LG 3 indicate that roles emerged spontaneously to some extent. In other words, the functional roles affected the organisation and coordination of the collaboration, and thus the impact of the instruction is validated. In addition, a plausible alternative interpretation for the observed PGE difference in the first study (Strijbos et al., 2004c) was disproved: the role groups with the highest (PD 2) and lowest (PD 1) PGE did not differ in their kappa value, illustrating that group members in the role group with a low level of PGE did not act more rigidly according to the functional roles. However, the variability in adherence to the functional roles (as expressed by the kappa values) shows that the roles acted as a guiding principle rather than as a set of coercive rules – which underlines the need for the computation of kappa instead of other statistical techniques. Two role behaviours (i.e., P and E) were frequently exerted by students in the nonrole groups, but these were not bound to a single group member, but distributed across all group members. Spontaneous roles emerged in two nonrole groups, but these group members still performed other role behaviours. Overall, the results indicate an overall involvement of each student in nonrole groups with the group task, especially where it concerns P-behaviour. The spread of E-behaviours in nonrole groups across members indicates that these groups organised their collaboration by splitting the content of the shared report into (sub)topics which were individually studied, written and subsequently assembled (A+B+C+D) in a 'collaborative' report. To some extent this behaviour seems to have occurred in some of the role groups as well, but appears to have been less consistent across these groups. Although it can be argued that this distribution enhances involvement in the task, it impedes the collaboration if the outcomes of individual study phases are not shared with other group members. The task-split approach could explain why less D-behaviours are observed as they were likely combined with E-behaviours.

In Study 2, the content analysis of communicative statements illustrates that the roles affected coordination. Similar to Study 1 the number of 'task coordination' statements was increased. A main effect was observed for the number of messages – but not for the segments – indicating that students in the role groups interacted more frequently than students in nonrole groups. More important, this difference in 'task coordination' replicates the earlier outcomes of the first study, however, the number of 'task content' statements did not increase in Study 2. Thus, changing the preconditions appears to have levelled out some of the disadvantages of the nonrole groups. The groups in both conditions were required to hand in progress reports and this may have stimulated content-focused contributions. Content analysis with respect to 'role behaviour', functional or spontaneous, revealed the same qualitative differences with respect to the collaboration process between role and nonrole groups. In contrast to Study 1, a significant difference was observed in the total amount of role behaviour. Compared to Study 1 the impact of the preconditions is reflected in the total amount of messages send and the role behaviours scored. A more even comparison regarding C-behaviour was possible as nonrole groups were required to hand in a progress every four weeks. Similar to Study 1, students in role groups predominantly performed their functional role behaviour more frequently than group members with a different role – again validating the impact of the functional roles. The kappa values for nonrole groups in Study 2 were again consistently low or very low and the slightly higher values for PD 7 and LG 1 indicate that roles emerged spontaneously to some extent. Three types of role behaviour were observed in the nonrole groups, but again distributed across all group members showing overall involvement. Finally, the spread of E-behaviours in nonrole groups – similar to Study 1 – was observed, indicating that these groups tend to split the task into individual topics. Spitting the task is very similar to a professional context where task allocation is often based on expertise. In fact, several role groups in both studies pursued this strategy to some extent. Although expertise roles can have a positive impact on the amount of information shared (see Stasser, Stewart, & Wittenbaum, 1995), it should be noted that students are not experts in a professional sense.

The results reported in this paper clearly underline that investigating functional roles during CSCL requires triangulation of data sources, analysis methods and outcomes. In fact, it can be argued that CSCL research in general requires triangulation because a variety of processes are studied simultaneously (e.g., learning, group efficiency, communication, social interaction, etc.) and the instruments used to measure these processes vary with respect to their quality, e.g. reliability. The outcomes of both studies reveal that functional roles stimulate coordination and overall group efficiency in a project-based CSCL course in higher education. Comparison of both studies reveals the possibility of a different added value of functional roles in educational environments with a varying degree of teacher-student control, such as small groups of students in an educational setting controlled by the teacher (Study 2) versus students in a community of learners who construct their own groups and learning opportunities (Study 1). It is clear that more research is needed to investigate the use of functional roles and the diversity of spontaneous roles – in controlled and uncontrolled CSCL environments – to support this interpretation.

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Identifying Peer Interaction Patterns and Related Variables In Community-Based Learning

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Abstract. The purpose of this study was to investigate patterns of peer interactions and to identify the relationships of peer interactions with learner characteristics and learning outcome in community-based learning. The participants were 24 middle school students joined in an online learning community for a week. Two patterns of peer interactions such as in-degree and out-degree centrality were identified. Students with high intra-personal or verbal-linguistic intelligence were related to high in-degree centrality, while students with high interpersonal intelligence or prior knowledge were related to high out-degree centrality. That means "self smart" or "word smart" students were popular and played knowledge broker's roles in their community. On the other hand, "social smart" students or "high prior knowledge" students were open and friendly activators and delivered vast information. Moreover, higher peer interactions were related to better learning outcome. These results indicated that peer interactions were important intervening variables to enhance learning effect.

Keywords: Community-based learning, peer interaction, learner characteristics, social network analysis

INTRODUCTION

With the rapid development of a knowledge-based society, it is of growing importance to create knowledge through collaboration with others beyond the individual. Recently, with the expansion of online communities, community-based learning has brought new learning methods where learners form communities around common objectives and create knowledge through interaction with other members (Bielaczyc & Collins, 1999; Palloff & Pratt, 1999; Rovai, 2003; Wilson & Ryder, 1998). However, research in community-based learning has been limited to conceptual and macroscopic studies such as the process of learning community development.

Therefore, we need to identify peer interaction patterns and relationships among the variables that promote peer interactions and learning effects in community-based learning. Thus, the purpose of this study was to investigate patterns of peer interactions and to identify the relationships of peer interactions with learner characteristics and learning outcome in community-based learning. The contribution of this study may provide practical guidelines for designing and operating strategies to enhance the effect of community-based learning.

THEORETICAL BACKGROUND

Community-Based Learning

General collaborative learning describes an instructional approach in which students work together in small groups to accomplish a common learning goal. Collaborative learning is based on these principles: (1) Tasks are carefully designed to be suitable for group work. (2) There is positive interdependence. (3) Students are individually accountable for learning and participation. (4) Attention and class time are given to interpersonal/collaborative skill building. (5) The role of the teacher changes from being "an instructor" to "a guide or a facilitator" (Johnson & Johnson, 1999). On the other hand, community-based learning is a learner-centered approach and based on the principles of collaborative knowledge construction and learning community. Students within the learning community set up common goals, generate ideas collaboratively, and share their production (Wilson & Ryder, 1998).

The process of community-based learning consists of five phases (figure 1). (1) Common goals assignment phase: students set up common goals and tune up member's demands and interests. (2) Group rules forming phase: students make group rules and distribute roles among members. (3) Assignment recognition phase: students recognize the problem of individual interests and experiences and carry out inquiry through discourse. (4) Collaborative accomplishment phase: students accomplish various collaborative activities such as intra-group and inter-group collaboration and interact with external specialist. (5) Production generation phase: students generate and share final production and also carry out peer evaluation and subsequent activity (Palloff & Pratt, 1999). Table 1 indicates five components of community-based learning environment include in collaborative learning, social interaction, planning & reflection, knowledge base, and evaluation & compensation (Kang & Byun, 2001; Stahl, 2000).

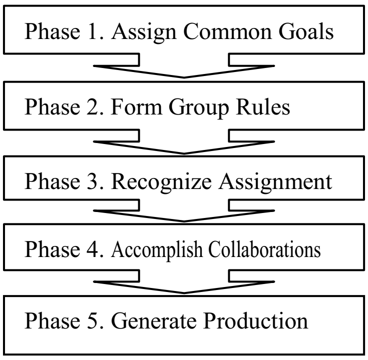

Figure 1. The process of community-based learning

Table 1. Five components of community-based learning environment

Dimension	Description	Function
Collaborative Learning	Exchange opinions and interact with members during group work	discussion, whiteboard, group workplace, communication tools, etc.
Social Interaction	Informal communication and recreation	free-board, announcement, Q/A, etc.
Planning & Reflection	Identify personal and group goal, plan time schedule for project, divide member' roles, and reflect learning process	reflection note, schedule, goal/ role specification, etc.
Knowledge Base	Share and Store learning resources and products	e-library, mybase, teambase
Evaluation & Compensation	Peer evaluation, instructor evaluation, internal/external compensation	evaluation rubrics, comment form, avatar-point, etc.

Learner Characteristics: Prior Knowledge & Three Personal Intelligences

This study included four learner characteristics: Prior knowledge, verbal-linguistic intelligence, interpersonal intelligence, and intra-personal intelligence. The reason why they were selected that students need to have abilities to learn through knowledge sharing, dialogical conversation skills, self-regulation ability, and interpersonal skills for enhancing student's learning effect in an online learning community (Bielaczyc & Collins, 1999; Jonassen & Land, 2000; Palloff & Pratt, 1999; Stahl, 2000).

Prior knowledge means that the individual already has knowledge regarding the problem or assignment. By reviewing previous literature, prior knowledge greatly affects the accomplishment process and achievement. Gardner's theory of multiple intelligences applied within K-12 and higher education research and practices and also described the way of learning styles (Gardner, 1999). According to a multiple intelligence approach, students with high verbal-linguistic intelligence ('word smart') learn best through language including speaking, writing, reading, and listening and have high achievement and good communication skills. Student with high interpersonal intelligence ('social smart') learn best through interaction with other people such as discussions, cooperative work, or social activities and enhance a friendly atmosphere and cohesiveness in groups. Students with high intra-personal intelligence ('self smart') learn best through meta-cognitive practices such as awareness of their feelings, self-reflection, thinking processes, and their own strengths and weaknesses. Self-smart students are good at end-goal setting, goal pursuing, and process assessment (Armstrong, 1994; Gardner, 1999).

Interaction Analysis: Social Network Analysis

Social network analysis is a sociological research tool. We can schematize social structure to a network composed of the link that connects a node to a node (node: participant, link: relation). Up to date, social network analysis appeared to apply a useful tool for analyzing participant interaction in the e-learning (Haythornthwaite, 2002; Palonen & Hakkarainen, 2000). It provided a new kind of in-depth information on communication relations, power relations, participant's role, and so on. Degree centrality of social network analysis was used as an instrument for analyzing the participant's interaction level and direction in this study.

In-degree Centrality & Out-degree Centrality

Degree centrality indicates the density of relationships between participants in a network and is presented by in-degree centrality and out-degree centrality (Figure 2).

A's In-degree Centrality = $\frac{\text{In-degree of A's connection}}{\text{Participants-1}}$	A's Out-degree Centrality = $\frac{\text{Out-degree of A's connection}}{\text{Participants-1}}$

Figure 2. Formulas of degree centrality

In-degree centrality means the degree of relations that behavior A receives the message from others in communication situations. Students with high in-degree centrality have more interactive activities for receiving information or comments from others. They are popular students or knowledge broker in their community.

On the other hand, out-degree centrality means the degree of relations that behavior A sends the message toward others in communication situations. Students with high out-degree centrality are more active in providing information to others in discussion or providing comments to other's opinions. They prefer to link open and friendly human relations to many participants and have important role to delivery information and data in their community.

METHODOLOGY

The subjects of this study were 24 first and second year middle school students joined in an online learning community operated by N company. The students accomplished a task that examined Greek-Roman mythology for one week. Based on a literature review of the process in community-based learning and previous studies on group interactions variables, a research model consisted of the input, process, and output variables: the input variables were four learner characteristics such as prior knowledge and three intelligences (verbal-linguistics, interpersonal, and intra-personal); the process variables involved two interactions such as in-degree centrality and out-degree centrality); the output variable was individual achievement.

The research instruments used in conducting the experiment were community-based learning environments, a learning task, prior knowledge test (Spearman-Brown formula / r = .66), multiple intelligence test (verbal-linguistic / interpersonal / intra-personal intelligence) (Cronbach's alpha = .67~.85) (Moon et al., 2001, adapted by Shearer, 1996), interaction analysis tools (social network analysis), and achievement evaluation rubrics (Wen, 1998). Data was gathered for a week and analyzed by social network analysis on interaction pattern using Netminer 2.0 tool and path analysis of learner characteristics, peer interaction, and learning outcome. Path coefficients were used as standardized regression coefficients (beta).

RESULTS

Peer Interaction Patterns Using Social Network Analysis

In-degree centrality of peer interaction

Figure 3 indicates that students s20(f), s17(f), s2(m), s3(f), s6(m), and s9(f) had higher in-degree centrality of interaction and positioned toward the center of the in-degree centrality circle. They received information or comments from others actively and were popular students and knowledge brokers in their community.

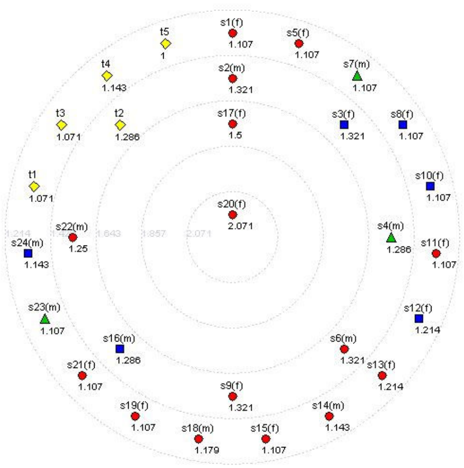

Figure 3. Social network analysis graph on in-degree centrality

s: student, t: mentor, (f): female, (m): male
Attributes: Verbal-linguistic intelligence
● : high (80~100 score) ■ : middle (60-79 score)
▲ : low (1~59 score) ◇ : mentor

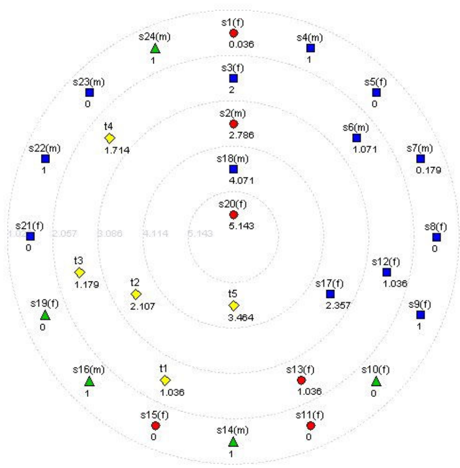

Figure 4. Social network analysis graph on out-degree centrality

s: student, t: mentor, (f): female, (m): male
Attributes : Prior knowledge
● : high (90~100score) ■ : middle (60~89 score)
▲ : low (1~59 score) ◇ : mentor

On the side of individual attributes, highly intrapersonal intelligent students (s2(m), s9(f), s17(f), etc.) or high verbal-linguistic intelligent students (s2(m), s9(f), s17(f), s20(f), etc.) (figure 3) had higher in-degree centrality. In addition, s2(m) and s20(f) students were not only high intrapersonal and verbal-linguistic intelligence but also high prior knowledge students. On the side of relational property, middle and high intrapersonal or verbal-linguistic students dominated in-degree interaction within this learning community. Furthermore, s3(f), s9(f), and s20(f) students interacted with mentors (t2, t4, t5) as well as peers actively.

Out-degree centrality of peer interaction

Figure 4 indicates that students s20(f), s18(m), s2(m), and s17(f) had higher out-degree centrality of interaction and positioned toward the center of the out-degree centrality circle. They actively participated and provided information and comments to other's opinions actively. They also linked human relations to many participants and have important roles in delivering information and data in their community.

On the side of individual attributes, middle and high interpersonal intelligent students (s2(m), 17(f), 20(f), etc.) or middle and high prior knowledge students (s2(m), s17(f), s18(m), s20(f), etc.) (figure 4) had higher out-degree centrality. On the side of relational property, middle and high interpersonal intelligence or prior knowledge students dominate interaction within this learning community. Moreover, students s2(m), s18(m) and s20(f) interacted with mentors (t2, t4, t5) actively

Meanwhile, two mentors (t2, t5) appeared to have high out-degree centrality. They connected with many students and provided students with guidance and information. In particular, students s2(m), s17(f), and s20(f) were higher out-degree centrality as well as higher in-degree centrality. The correlation of in-degree centrality and out-degree centrality was high (Kentall's tau τ =.796, p < .05, n = 24). However, students receiving many messages were not necessarily providing many comments to others.

Relationships among Learner Characteristics, Peer Interactions, and Learning outcome Using Path Analysis

The results of path analysis (table 2) indicate that first, variables of learner characteristics affecting high in-degree centrality were intra-personal intelligence (β = .396) and verbal-linguistic intelligence (β = .235) more than prior knowledge and interpersonal intelligence. Conversely, variables of learner characteristics affecting interactions of high out-degree centrality were interpersonal intelligence (β = .286) and prior knowledge (β = .230) more than verbal-linguistic and intra-personal intelligence.

Table 2. Path coefficients among variables (n = 24)

Independent Variables	Dependent Variables			
	In-degree		Out-degree	
	Peer interactions	Learning outcome	Peer interactions	Learning outcome
prior knowledge	-.111	.367	.230	.301
verbal-linguistic intelligence	.235	.189	-.019	.220
interpersonal intelligence	-.263	-.093	.286	-.189
intra-personal intelligence	.396	-.099	-.083	-.034
peer interactions		.115		.232

Second, prior knowledge (β = .367(in-degree), β = .301(out-degree)) and verbal-linguistic intelligence (β = .189(in-degree), β = .220(out-degree)) among learner characteristics were related to learning outcome when in-degree and out-degree centrality mediated. Finally, the path coefficients for in-degree and out-degree interaction direct effect on learning outcome were .115(in-degree) and .232(out-degree). The effect on learning outcome of out-degree interaction was higher than that of in-degree interaction.

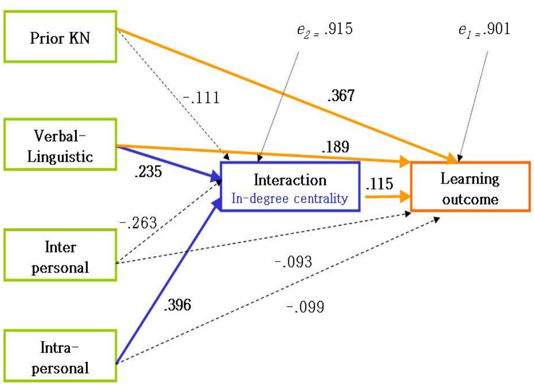

Figure 5: Path analysis of learning outcome intervened by in-degree centrality

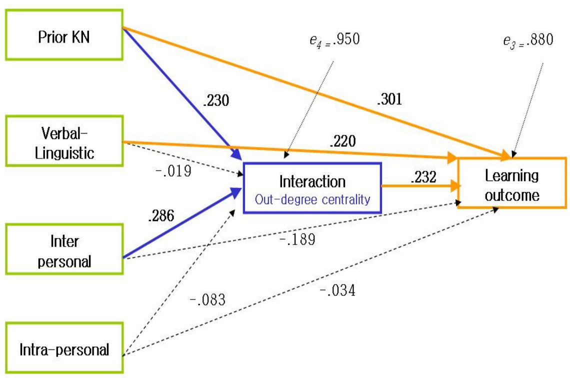

Figure 6: Path analysis of learning outcome intervened by out-degree centrality

positive effect negative effect e_1/e_3 : error to learning outcome e_2/e_4 : error to peer interaction

CONCLUSIONS

There are two conclusions. First, students with high intra-personal and verbal-linguistic intelligence were related to high in-degree centrality, while students with high interpersonal intelligence and prior knowledge were related to high out-degree centrality. In other words, "self smart" and "word smart" students were reflectors and good communicators in the learning process. These students were popular and played knowledge broker's roles in their community. On the other hand, "social smart" students and "high prior knowledge" students were open and friendly activators and delivered vast information in the learning community (Rovai, 2003).

Second, prior knowledge and verbal-linguistic intelligence among learner characteristics were related to learning outcome. Also, higher peer interactions were related to better learning outcome. These results indicated that peer interactions were important intervening variables that enhanced learning effects beyond the functional role of communication in community-based learning. Furthermore, higher peer interaction in an online learning community, as a knowledge network, may affect intangible outputs such as cohesiveness, trust, and sense of community as well as tangible outputs such as learning achievement and problem solving (Wen, 1998).

A limitation of this study was that the sample size was very small, reducing verification of the study. Twenty-four middle school students took part in the study. Thus it is required to obtain a larger sample size in extended period of time for future research. In addition, this study is needed to use not only quantitative analysis such as social network analysis but also qualitative methods such as interviews, questionnaires and message analysis for analyzing in-depth learner interaction patterns.

The implications of this study include that degree centrality of SNA is able to used as a measuring method for analyzing peer interactions in collaborative learning activities. Moreover, the result of relationships of peer interactions with learner characteristics and learning outcome may provide guidelines for developing learner model and collaborative supported mentoring agents in CSCL.

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Technology Affordances for Intersubjective Learning: A Thematic Agenda for CSCL

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Abstract. After a brief survey of epistemologies of collaborative learning and forms of computer support for that learning, the study of technology affordances for intersubjective learning is proposed as a thematic agenda for CSCL. A fusion of experimental, ethnomethodological and design methodologies is proposed in support of this agenda. A working definition of intersubjective learning as joint composition of interpretations of a dynamically evolving context is provided, along with an outline for analysis under this definition.

Keywords: CSCL research agenda, interactional practices, representational guidance

INTRODUCTION

The primary purpose of this paper is to propose a thematic agenda for the second decade of Computer Supported Collaborative Learning (CSCL). Koschmann (2002) has characterized CSCL as the study of "practices of meaning-making in the context of joint activity and the ways in which these practices are mediated through designed artifacts." I accept but elaborate on this definition, and organize my presentation accordingly. The proposal is motivated by an overview of various concepts of "collaborative learning" in terms of their underlying epistemologies, and the different forms of "computer support" explored by practitioners for these notions of learning. I then present my view of where the "soul" of CSCL lies within the diversity of this "body" of work. My presentation is analytic rather than empirical, making a case for what *should* be the thematic focus of CSCL based on identification of those problems in the nexus of computer mediation and collaborative learning that are our special concern.

EPISTEMOLOGIES FOR COLLABORATIVE LEARNING

Any complete CSCL research agenda will be based on assumptions, implicit or explicit, concerning the question of what it means to learn in collaborative settings. If we define *learning* to mean gaining new knowledge, then this is an epistemological question. For purposes of brief exposition, the epistemologies will be presented in terms of their most distinguishing commitments, so are necessarily oversimplified.

A *knowledge-communication epistemology* (Wenger, 1987) is common in the CSCL literature (e.g., Bromme, Hesse & Spada, 2005). Knowledge communication is "the ability to cause and/or support the acquisition of one's knowledge by someone else, via a restricted set of communication operations" (Wenger, 1987, p. 7). Under this epistemology, CSCL research examines how to more effectively present knowledge in some medium, or how to otherwise ensure that communications can "cause and/or support" the desired acquisition of knowledge. However, many authors in CSCL place greater emphasis on epistemologies that are more constructivist and more interactional.

A *constructivist epistemology* (Piaget, 1976; von Glaserfeld, 1995) emphasizes the agency of the individual learner in the learning process. Learning can only happen through the learner's efforts to make sense of the world, although a mentor might arrange for the learner to have rich yet problematic experiences in order to accelerate the change process. Computer support for such experiences includes simulations and "microworlds" (Rieber, 2004). CSCL researchers rarely take this view to its solipsistic extreme. Instead, constructivism takes the form of "collaborative knowledge construction" (Stahl, 2000), implying an interactional constructivist epistemology.

An *interactional epistemology* suggests that we examine how interactions between people lead to learning. Many CSCL authors (e.g., Baker, Hansen, Joiner & Traum. 1999; Rummel & Spada, 2005; van Der Pol, Admiraal & Simons, 2003) build their interactionalism on the metaphor of "common ground" from Clark's contribution theory (Clark & Brennan, 1991). Pfister (2005) proposes that adding knowledge to common ground "is the gist of cooperative learning: going from unshared to shared information." See Koschmann & LeBaron (2003) for a critique of the concept of "common ground."

A more radically interactional epistemology, which I shall call *intersubjective learning*, goes beyond an information sharing conception of collaborative learning in two ways: it can be about sharing *interpretations* as well as information, and these interpretations can be *jointly created* through interaction, in addition to being formed by individuals before they are offered to the group. *Intersubjectivity* is to be understood in a participatory sense, and may involve disagreement as well as simple sharing of information (Matusov, 1996). In this epistemology, learning is not only accomplished through the interactions of the participants, but also *consists of* those interactions (Koschmann et al., 2005).

Social theories of learning all incorporate interactional epistemologies, but vary from merely placing learning in a social context to making commitments to intrinsically *social* (and hence intersubjective) *epistemologies*. A social-as-context view might maintain that learning remains fundamentally a process within individual minds, yet this process can be enhanced through contacts with other minds. Cognitive dissonance theory (Festinger, 1957) and socio-cognitive conflict theory (Doise & Mungy, 1984) can be read this way. Developmental learning through social interaction can be understood as the internalization of interpersonal processes as intrapersonal processes (Vygotsky, 1978). A participatory epistemology conceives of individual learning as a process of becoming a member of a community by acquiring that community's cultural practices and world-view through "legitimate peripheral participation" (Lave & Wenger, 1991). In this view, "learning is an integral part of generative social practice in the lived-in world" (Lave & Wenger, 1991, p. 35)—a process that constructs personal identity, but also entwines individual learning with group learning. Although social systems are organized to replicate themselves, they can "learn" when local innovations undertaken in response to internal tensions and external disturbances redistribute activity across the system (Cole & Engeström, 1993). The new practices can be reflected in concomitant creation of novel artifacts that support and help to replicate these practices (Wartofsky, 1979).

Another social epistemology is *knowledge building*, which should not be confused with the superficially similar *knowledge construction.* Knowledge building is a collective version of Scardamalia and Bereiter's (1991) *intentional learning*—the "deliberate effort to increase the cultural capital [of a society]" (http://ikit.org/kb.html, accessed April 2005). The essential difference between knowledge building and other forms of learning is that members of a knowledge building community through their own collective agency expand the boundaries of their knowledge by periodically reflecting on the limits of their understanding and choosing actions that address these limitations. As Cole & Engeström (1993) put it, deliberate transcendence of an activity structure requires that participants reflectively identify what they want to transcend.

For the purposes of this paper, I will use *collaborative learning* to encompass all socially contextualized forms of learning. The other phrases are layered in the following manner: *knowledge construction* recognizes that individuals create their world view rather than just receiving it preformed from others; *collaborative knowledge construction* more specifically locates this meaning-making in a group context; *intersubjective learning* further specifies that the process of meaning-making is itself constituted of social interactions; and *knowledge building* requires that this group-based meaning-making is being done intentionally.

CS: COMPUTER "SUPPORT" OR MEDIATION

Let us now add computers to the mix. In what ways can we bring technology to bear on the problem of supporting collaborative learning, as it is variously conceived? This section identifies three major ways in which technology can be applied to support collaborative learning: as medium, constraint, and resource. The prior discussion is relevant because our choice of an epistemology of collaborative learning can affect how we approach the design of computer mediation and what questions we ask in our research. For example, under a knowledge-communication model, we might think about the information technologies we are designing as communication channels, focusing on the ease with which one can move information and interpretations of that information between participants. Under an intersubjective learning model, we might design information technologies as forums within which new ideas can be discovered and evaluated. However, it is also possible to support collaboration without making any particular commitment to a theory of collaborative learning. I begin with this epistemologically minimalist approach.

Technology as Medium

People often resort to computer-mediated communication (CMC) as a substitute for face-to-face interaction in order to make communication possible between people at different locations (synchronous distance communication) or at different times (asynchronous communication). It is not surprising that face-to-face (FTF) communication would then be taken as the standard against which CMC is evaluated (Olson & Olson, 2000). Research in this tradition tries to improve the bandwidth and multimodality of CMC technology and fine-tune its design to match the characteristics of FTF. For example, gaze and gesture are demonstrably vital cues in FTF interaction, so some researchers study how to arrange cameras such that the remote image of a person gives a more accurate indication of what they are looking or pointing at (e.g., Kato et al., 2001). Although FTF interaction has great value, we should not assume that online replication of FTF learning is a goal of CSCL, for four reasons.

First, CSCL does not necessarily replace FTF interaction. Computational artifacts can also augment spoken and gestural communication between co-present collaborators (Roschelle, 1994; Suthers & Hundhausen, 2003), and be embedded in classrooms where much of the interaction is FTF (Lingnau, Hoppe & Mannhaupt, 2003; Scardamalia & Bereiter, 1991; Toth, Suthers & Lesgold, 2002).

Second, although further progress can be made, ultimately the goal of replicating FTF interaction online may not be achievable. "Distance matters" (Olson & Olson, 2000) in many subtle ways when collaborating through technology. Even with extremely high bandwidth communication in multiple modalities, advantages of spatial co-location will be difficult to replicate online, such as access to implicit contextual information, gaze and gesture as cues for identifying deictic referents, and the use of space to organize ideas and coordinate action.

Third, it is not sufficient for CSCL to merely replicate FTF interaction. As Pfister (2005) puts it "even if virtual reality is achieved ... genuine learning discourse is not supported. It is completely up to the participants ... how to structure the learning process." Rather than leaving efficient learning up to the learners, CSCL has an obligation to design technology that supports effective collaborative learning. In order to do so, some commitment to an epistemology of effective collaborative learning is necessary.

Fourth, CSCL can explore the advantages of going "beyond being there" (Holland and Stornetta, 1992): ways in which CMC is actually *better* than FTF. An obvious example is that CMC "turns communication into substance" (Dillenbourg, 2005), providing additional resources for learning. The record of communication and shared representations that are manipulated during communication provide a shared persistent information base that enables the community of collaborators to reflect and act on its own state of understanding—to reinterpret, find connections between, refine and expand information and ideas explored over time.

Research that focuses primarily on supporting collaboration through CMC is not at the center of CSCL in that it does not necessarily directly address issues of learning. However, nor is such research peripheral to CSCL. Indeed, understanding the unique affordances for collaboration offered by technology is as foundational to CSCL as understanding learning. (In this paper, "affordances" is used in Norman's (1999) sense of "perceived affordances.) Much further work is needed to answer questions such as: What strategies do people use to manage collaboration via written and other artifact-mediated means? How are the affordances of various media (including information technologies) appropriated to carry out these strategies? How then can we design our CMC and CSCL environments to provide those affordances with the most natural match to required communication strategies? (Dwyer & Suthers, 2005).

Technology as Constraint

Information technologies, as well as other technologies such as paper based instructional materials, are often applied to education as means to limit the options available to learners. Although it sounds negative, this is sometimes a useful strategy.

Properly applied, constraints on activity can resolve a paradox of collaborative learning. Collaboration imposes an additional task on the learners: in addition to choosing actions within the problem domain and attending to what they are learning from those actions, they must also manage interpersonal relations and group functioning (Whitworth, Gallupe & McQueen, 2000). Learning may be reduced if less cognitive resources are dedicated to the learning task. However, if learners can help each other with different parts of the learning activity, collaboration can reduce task load and can increase learning effectiveness through activities that are more difficult to do alone, such as argumentation, explanation and reflection (Andriessen, Baker & Suthers, 2003; Slavin, 1995). To resolve this paradox, instructional technology is often designed to structure part of the collaborative learning activity, "offloading" work onto the technology so that learners can focus their cognitive and social resources on other relevant aspects of the learning activity. The technology support can take different forms, such as full automatization of the offloaded task, constraining actions to reduce the need to make decisions and the risk of errors while executing the task, or non-mandatory guides such as coaching agents or representational guidance. Whatever form it takes, this support might be subsequently removed (the "scaffolding" "fades" in this mixed metaphor) as learners internalize the guidance it provided.

Technology constraints can also be used to enforce a learning agenda. Analysis of the learning task may reveal prerequisites, or uncover difficulties that are best left for after fundamental skills are learned. Then, guidance is applied via any of the methods previously listed (automatization, interface constraints, coaches, representational guidance) to ensure that skills are acquired in an optimal order. The choice of what parts of the task are "scaffolded" and when and how "fading" occurs can be an effective use of technology to implement a learning agenda. Similarly, constraints can be used to enforce a collaboration protocol, perhaps even one based on an epistemological commitment as to what constitutes effective learning through collaboration (e.g., Weinberger, Reiserer, Ertl, Fischer & Mandl, 2005) For example, several researchers have identified collections of conversational moves that they believe are necessary for an effective learning dialogue, and implemented these moves as mandatory sentence openers in a communication interface (e.g., Baker & Lund, 1997).

Technology as Resource

Finally, we can view technology as a resource to be drawn upon to support the process of learning collaboratively. CMC environments record communication in a persistent medium that can support reflection and interpretation. Disciplinary representations such as models, simulations and visualizations also serve as resources for conversation. Rather than being vehicles for communicating expert knowledge, they become objects about which learners engage in sense-making conversations (Roschelle, 1994) and can be designed to lead to productive conversation. Another example of how technology can serve as a resource for collaborative learning is technologies that foster *group awareness* (e.g., Erickson et al. 2002). The mere awareness that others are present and will evaluate one's actions may influence one's choice of actions. Information about the attentional status of group members and their attitudes towards previously proposed ideas may influence the actions of individuals in the group. Visualizations of conflict or agreement between members may lead to further argumentation or reaching of consensus.

There is some overlap between technology as medium, constraint (or guide), and resource. Consider shared representations such as argumentation and modeling tools. Collaborators may feel some obligation to discuss proposed or just-taken actions on shared representations with their partners. The potential for action offered by the representational notation will influence the actions that are discussed; thus the representation guides conversations towards those ideas motivating the afforded actions (Suthers & Hundhausen, 2003). Also, jointly constructed representations become imbued with meanings for the participants by virtue of having been produced through a process of negotiation. These representational constituents then enable easy reference to prior ideas with deictic reference (through gesture or language), or by direct manipulation (Suthers, Girardeau, & Hundhausen, 2003). The expressive and indexical affordances of a representational medium will affect its value as a resource through these processes.

A THEMATIC AGENDA FOR CSCL

Building on the foregoing account of epistemologies of and forms of computer support for learning, I now propose and make the case for the research agenda with which we should begin the next decade of CSCL.

What To Study?

The Interactional Accomplishment of Intersubjective Learning

Koschmann's definition of CSCL as being concerned with the "practices of meaning-making in the context of joint activity" can be understood under many of the epistemologies previously discussed. Like the Hindu parable in which several blind men feel an elephant and each describe it differently, all are describing some aspect of the truth. However, the question we face is how to most productively focus our research efforts: which aspect of the elephant do we now most need to understand?

The aspect of collaborative learning that is least understood is what I have been calling *intersubjective learning*. As previously discussed, this is learning that is not only accomplished interactionally but is also *constituted of* the interactions between participants. Following Garfinkel, Koschmann et al. (2005) argue for the study of "member's methods" of meaning making: "how participants in such [instructional] settings actually go about *doing* learning" (emphasis in original). In addition to understanding how the cognitive processes of participants are influenced by social interaction, we need to understand how learning events themselves take place in the interactions between participants. The study of joint meaning making is currently not prominent as a topic of study in our field: it is difficult to find research publications within CSCL that directly address this epistemology. Even where process data (rather than outcome data) is examined in detail, the analysis is typically undertaken according to coding categories that count features that are essentially proxies for the phenomenon of interest rather than seeking to uncover those phenomena directly.

A few studies published in the CSCL literature have addressed this problem directly, for example, Koschmann et al. (2003), Koschmann et al. (2005), Roschelle (1994), and Stahl (in press). Koschmann's work has generally focused on participants' methods of *problematization*: identifying a situation as problematic and requiring further analysis, possibly leading to a change of conception. This research is only the beginning. We also need to identify methods for resolving the problematized issue. I speculate that these will include methods for exploring interpretations (argumentation) and negotiating an interpretation that is sufficient to meet the task demands (achieving a working consensus).

Stahl (in press) argues that small groups are the most fruitful unit of study, for two reasons. Most simply, small groups are where members' methods for intersubjective learning can be observed. Groups of several members allow the full range of social interactions to play out, but are not so large for participants and researchers alike lose track of what is going on. More compellingly, small groups lie at the boundary of and mediate between individuals and a community. The knowledge building that takes place within small groups becomes "internalized by their members as individual learning and externalized in their communities as certifiable knowledge" (Stahl, in press). However, small groups should not be the only social granularity studied. Analysis of large-scale changes in communities and organizations may lead to understanding of emergent social learning phenomena as well as elucidate the role of embedded groups in driving these changes.

The study of the interactional accomplishment of intersubjective learning gives rise to interesting questions that are among the most challenging facing any social-behavioral science, and even touches upon our nature as conscious beings. Do cognitive phenomena exist transpersonally? How is it possible for learning, usually conceived of as a cognitive function, to be distributed across people and artifacts? How can we understand knowledge as accomplished practice rather than as a substance or even predisposition? Yet I would not leave individual learning behind. In support of this research agenda, cognitivists can ask: What is the relationship of the change process we call "individual learning" to that individual's participation in socially accomplished learning?

Technology Affordances for Intersubjective Learning

The second half of Koschmann's definition of the domain of CSCL is "the ways in which these practices [meaning-making in the context of joint activity] are mediated through designed artifacts." Computer support for intersubjective meaning making is what makes our field unique. Other fields have investigated computer support for collaboration, intersubjective meaning making, and computer support for other models of learning such as knowledge-communication and constructivism. What form of support is most fruitful for CSCL research?

I propose that the technology side of the CSCL agenda should focus on the *design and study of fundamentally social technologies* that are *informed by the affordances and limitations of those technologies*. CSCL systems should be fundamentally social because interactional and especially intersubjective epistemologies of learning require this. To be fundamentally social means that the technology should be designed specifically to mediate and encourage social acts that constitute group learning and lead to individual learning. To be informed by the affordances and limitations of a technology means that the design attempts to leverage the unique opportunities provided by the technology rather than replicating support for learning that could be done through other means, or (worse) trying to force the technology to be something for which it is not well suited.

There are many ways in which a technology can be used to implement support for collaborative learning that are not intrinsic to the technology itself. For example, consider the scripting of interactions (e.g., Weinberger et al., 2005). We might study the effects of asking a group to go through phases of collaboration, or script the interaction at a finer grain, providing protocols for making and evaluating proposals. These interventions could just as well be done with paper, or even verbal instructions. There are clear advantages to using information technology, such as support for distance interaction and automated prompting, but the primary variable being studied is not itself a property of information technology (see also Dillenbourg, 2002). Such research is valuable and can be embraced within CSCL, but is not at the core of the proposed agenda.

More intrinsic to information technology as a topic of study is the generalized question of how the affordances of information technology can be appropriated to support intersubjective learning in action. What is unique to information technology that can potentially fill this role?

The computational medium is reconfigurable. Representations are dynamic: It is easy to move things around and undo actions. It is easy to replicate those actions elsewhere: one can bridge time and space. These features make information technology attractive as a "communication channel," but we should exploit technology for its potential to make new interactions possible, not try to force it to replicate face-to-faced interaction.

CMC environments "turn communication into substance" (Dillenbourg, 2005). A record of activity as well as product can be kept, replayed, and even modified. We should explore the potential of the persistent record of interaction and collaboration as a resource for intersubjective learning.

Computational media can analyze workspace state and interaction sequences, and reconfigure itself or generate prompts according to features of either. We should explore the potential of adaptive media as an influence on the course of intersubjective processes. We need not anthropomorphize the medium to take advantage of its ability to prompt, analyze and selectively respond.

Human communication and use of representational resources for this communication is highly flexible: we cannot "fix" meanings or even specify communicative functions (Dwyer & Suthers, 2005). Informed by this fact, CSCL research should identify the perceived affordances of computational media, and explore how these affordances are appropriated by collaborators and how they influence the course of that collaboration. We then design technologies that offer collections of affordances through which participants can interactionally engage in learning with flexible forms of guidance.

How To Study It?

I consider this question in terms of the major methodological traditions of CSCL and a specific analytic approach that is motivated by an operational definition of intersubjective learning.

A Call for Methodological Fusion

CSCL can presently be characterized as consisting of three methodological traditions: experimental, descriptive (e.g., ethnomethodological), and iterative design.

Many empirical studies follow the dominant experimental paradigm that compares an intervention to a control condition in terms of one or more variables (e.g., Baker & Lund, 1997; Rummel & Spada, 2005; Suthers & Hundhausen, 2003; Van Der Pol et al., 2003; Weinberger et al., 2005). Data analysis in most of these studies is undertaken by "coding and counting:" interactions are categorized and/or learning outcomes measured, and group means are compared through statistical methods in order to draw generalizable conclusions about the effects of the manipulated variables on aggregate (average) group behavior. As discussed previously, typical studies do not directly analyze the accomplishment of intersubjective learning. Such an analysis must examine the structure and intention of specific cases of interaction rather than count and aggregate behavioral categories.

The ethnomethodological tradition, exemplified in CSCL by Roschelle (1994), Koschmann et al. (2003) and Koschmann, et al. (2005), is more suited for such case analyses. Video or transcripts of learners or other members of the community are studied to uncover the methods by which participants accomplish learning. The approach is data-driven, seeking to discover patterns in the data rather than imposing theoretical categories. The analysis is often microanalytic, examining brief episodes in great detail. Descriptive methodologies are well suited to existentially quantified claims (e.g., that a community sometimes engages in a given practice). Yet, as scientists and designers we would like to make causal generalizations about the effects of design choices. Descriptive methodologies are less suited for claiming that an intervention has an effect, the province of experimental methodology.

The traditional analysis methods of experimental psychology miss the methods through which learning is accomplished—intersubjective meaning making—but this does not imply that we should all become ethnomethodologists. Rather, the foregoing considerations suggest that we explore hybrid research methodologies, drawing upon the strengths of both (Johnson & Onwuegbuzie, 2004). Experimental designs can continue to compare interventions, but the comparisons would be made in terms of microanalyses of how the features of information technology influence and are appropriated for members' methods of joint meaning-making. Conceptually, the process analysis changes from "coding and counting" to "exploring and understanding" ways in which design variables influence support for meaning-making. Such analyses are time intensive: we should explore instrumentation of our learning environments and automated visualization and querying of interaction logs as research aids. Traditional analyses, especially measures of learning outcomes but also "coding and counting," might also be retained to obtain quick indicators of where more detailed analyses are merited, thereby focusing the detail work.

The iterative design tradition is exemplified by Fischer & Ostwald (2005), Lingnau, et al. (2003) and Guzdial et al. (1997). Driven by the dialectic between theory and informal observations and engaging stakeholders in the process, design-oriented researchers continuously improve artifacts intended to mediate learning and collaboration. Their research is not necessarily qualitative or quantitative, but may also be "quisitive" (Goldman, Crosby, Swan & Shea, 2004). Exploring design is a valuable component of the overall CSCL portfolio of research strategies. It is not enough to just observe people's behaviors and describe the contingencies of these behaviors with respect to technology affordances. We are trying to uncover the potential affordances of information technologies, so need to explore the "space" of possible designs, pushing into new areas and identifying promising features that should receive further study under the other methodological traditions. Designers also need to conduct microanalysis of collaborative learning with and through technology in order to identify the affordances of designed artifacts that seem to be correlated with effective learning episodes. Yet the marriage need not relegate descriptive methodologies to roles subservient to "design as usual." A conversation between the theoretical assumptions of ethnomethodology and those of design can lead to a "technomethodology" that changes the very objectives of design (Button & Dourish, 1996).

A potential limitation of descriptive methodologies should be noted. If we focus on finding examples of how members accomplish effective learning, we may miss abundant examples of how they also fail to do so. Yet in order to find that something is not there, we need to have an idea of what we are looking for. A purely data-driven approach that derives but never applies theory won't be adequate. Descriptive methods can be modified to address this need. Common patterns found in successful learning episodes subsequently become the theoretical categories we look for elsewhere, and perhaps do not find in instances of unsuccessful collaboration. Having identified where the successful methods were *not* applied, we can then examine the situation to determine what contingency was missing or responsible. Care should be taken, however, to make sure that in finding case examples where the interactional accomplishment of learning is absent we do not fail to notice where something else of value to the participants *is* being accomplished! For example, establishment and maintenance of individual and group identity are also worthwhile accomplishments as far as the participants are concerned (Whitworth et al., 2000), and indeed are a form of learning.

Eclectic Analysis of Composition of Interpretations

In the proposal under consideration, researchers from all methodological traditions will include microanalyses in their toolbox. Although methods for microanalysis of conversation are well developed, how do we conduct such an analysis of computer-mediated collaboration? In this final section I describe a framework that I am developing and so far have found to be useful. This discussion draws on an analysis of participant's manipulations of a shared workspace during synchronous online collaboration in order to determine whether and how such actions can be understood as accomplishing collaborative knowledge construction (Suthers, 2005). I begin with a tentative definition that I use to guide the work.

Knowledge construction is (and is evidenced by) the *composition of interpretations of a dynamically changing context*. "Interpretations" are acts that create and modify ideational entities. Ideational entities exist when evoked in human cognitive and social activity, and may also be "represented" when the interlocutors sharing a medium interpret the inscriptions in the medium as evoking such ideas. An act of interpretation may take the form of predications, commentary, restatements, or expressions of attitude (for example), enacted verbally, gesturally, or through manipulations of representations. "Composition" is the cumulative effect of interpretive acts on those ideational entities: each interpretive act in a sequence acts on the ideation resulting from the previous interpretive act, analogous to composition of functions in mathematics. (Since the ideational entities form part of the context, this is one way the context changes.) *Collaborative* knowledge construction (including intersubjective learning) takes place when multiple participants contribute to this composition of interpretations. The important point is that *the joint composition of interpretations is the gist of intersubjective learning* (not "going from unshared to shared information"). No commitment to mutual beliefs residing in some Platonic realm is necessary.

Collaborative knowledge construction requires interactions between participants, so the analysis begins by identifying *uptake* events in which one participant takes up another's contribution and does something further with it. Contributions may include attentional orientation, information, or expressions of attitude. Uptake is possible in any medium through which contributions are shareable. Examples of uptake include "A has said P, B has responded with Q," "A says P and B expresses (dis)agreement," "A brings O into the workspace, and B also begins to consider O," "A has created object O1; B has changed it to O2," "A has created O1 and B has created O2; now A combines O1 and O2 in such a manner," etc.

Once we have identified uptake events, we need to recognize what the participants have jointly accomplished through sequences of uptakes, and we need to identify the potential influence or utilization of technology affordances in this accomplishment. What do we look for in order to identify the interpretive act accomplished through the uptake? Intersubjective learning and knowledge building involve multiple processes (see the model in Stahl, in press), and we may elect to support different aspects of these processes (as discussed in the first half of the paper). Therefore we should not expect one theory to do the entire job for us. An eclectic approach that "triangulates" from multiple theoretical perspectives is necessary due to the complexity of the problem we are tackling. We can draw upon various theories for insights on what counts as interpretive acts and what those acts mean for the learning of individuals and groups. I illustrate below with strategies taken in Suthers (2005).

Contribution theory (Clark & Brennan, 1991) suggests that we look for presentation/acceptance pairs in which *one participant's action in the medium is taken up by another participant in a manner that indicates understanding of its meaning.* The signal of acceptance is often implicit, so can be difficult to identify. For example, it can consist merely of continuing the interaction. But implicitness is a property of interaction, not a limitation of the analysis method. More damaging, an analysis based solely on contribution theory at best can tell us only how people check *that* they have achieved mutual understanding, but does not inform us about the process *by which* this mutual understanding is reached. Therefore the theory will be of limited value in understanding what kinds of interactions lead to learning, and whether these are supported by our interventions.

Social and socially contextualized theories have more to say about how learning is accomplished through interaction. Representations that externalize one's beliefs can make beliefs explicit enough for one's interlocutors to notice conflicts, thereby initiating a socio-cognitive process of learning (Doise & Mugny, 1984). As analysts, we look for situations in which *the externalization of ideas led to identification of commonalities and differences of interpretation that were subsequently taken up by at least one of the individuals involved*. In addition to overt verbal argumentation, clues that conflict is being addressed include revision or deletion of the others' ideas or the use of an explicit conflict relation between one's own and others' ideas, if the medium provides for such relations.

The foregoing perspective is limiting in that it treats participants as separate cognitive entities that interact via language and (other) notations, yet retains the locale of knowledge construction activity within the individual. A distributed cognition perspective (Hollan, Hutchins & Kirsch, 2002) suggests that cognitive activities such as knowledge construction are distributed across individuals and information artifacts through and with which they interact. The information-transformative and interpretive components of intersubjective learning can occur across multiple individuals via external representations. Under the distributed cognition perspective we would look for *transformations of representations across individuals where those transformations can be collectively interpreted as a cognitive process*.

The cultural-historical activity theoretic (CHAT) perspective (Cole & Engeström, 1993) considers how activity is formed within and changes a larger context that includes not only the self and the object or topic of interest, but also tools, one's community, one's role in this community, and the norms for behavior in the community. CHAT is complex and not easy to summarize in passing. Here I focus on the concept of *mediation*. When we examine the relationship between any two elements of an activity system (the subject, object, tool, community, roles, rules), we can sometimes benefit from asking how a third element mediates the relationship between the first two, influencing the form the relationship takes. For example, external representations can mediate between individual and community by crystallizing prior practice. Under a mediation perspective, we might analyze collaborative use of representations by looking for *ways in which the representation mediates (makes possible and guides) interactions between participants*. The creative acts afforded by a given representational notation may affect which negotiations of meaning and belief take place. For example, we would look for *discussions initiated as participants prepare to modify a representation* and also identify *ways in which participants use representations as resources for referring to ideas* (Suthers & Hundhausen, 2003).

There are other theories that can be applied to the process of generating researchers' interpretations of uptake relations as evidence of participants' interpretations of their dynamically evolving context. It is my sense that we have at our disposal a powerful repertoire of theories of learning and social interaction, and have not yet fully explored the analytic power of this repertoire. Although I welcome any new (or revived) theories that provide fresh perspectives on the problems of CSCL, I would not want to see the field neglect to explore the power of our present theoretical toolkit as we rush to align our work with the vogue theory of the year. It will take the next decade to work out the implications of those we already have at our disposal.

CONCLUSIONS

CSCL is a field that is establishing basic yet sometimes peripheral findings as it seeks its center. Work currently being undertaken in the field encompasses several epistemologies of collaborative learning, and leverages information technology as communication medium, as a constraining and guiding medium, and as a resource for collaboration. However, there is an emerging awareness that we need to grapple with the central and most unique problem of CSCL: processes of intersubjective learning, and how technological affordances mediate or support such processes. A framework for analysis was offered that suggests interpretation of basic "uptake" actions in terms of cumulative composition of interpretations of a shared context, examining how representational and other technological affordances guide action by offering potentials and constraints, and how affordances of the "substance" CMC makes out of communication can serve as resources for conversation, reflection, and group awareness.

Research methodology in CSCL is largely trichotomized between experimental, descriptive and iterative design approaches. Although sometimes combined within a single research project, the methodologies are even then typically kept separate in companion studies or separate analyses of a single study. This situation can be productive for a little longer, as the experimentalists continue to identify variables that affect general parameters of collaborative behavior, while the ethnomethodologists identify patterns of joint activity that are essential to the meaning-making and learning we all seek to support. However, very soon CSCL needs experimentalists to study dependent variables that directly reflect the phenomenon of interest, the ethnomethodologists to look for *predictive* regularities in technology mediated meaning making that can inform design, and the designers to generate and assess promising new technology affordances in terms of the meaning-making activities they enable. Mutual assistance is possible through hybrid methodologies, for example applying richer descriptive analytic methods to the problem of understanding the implications of experimental manipulations and new designs, and through computer support for our own meaning-making activities as researchers.

The critiques put forth by this paper apply to my own current work as well as others' and have demanded shifts in my own thinking. Perhaps these critiques also reflect impending shifts in our field—towards the study of practices of intersubjective learning and how these practices are mediated by technology affordances.

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Using Paper to Support Collaboration in Educational Activities

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Abstract. This paper describes findings from a pilot study that compared the collaborative use by children of three different media formats: a paper book, a CD-ROM in a standard PC set-up, and a paper booklet augmented with digital content. These findings show how the book's ergonomics provide a flexible and easily accessible interface which engenders fluid collaboration between pairs of children. These qualities are also observed when children work with the augmented paper booklet. The value of digital content is demonstrated in a participatory design activity, where we find how digital media can 'bring to life' the information presented on paper. In contrast to developments focused narrowly on new technologies, this study presents evidence for the use and value of paper, and paper augmented with digital media, in educational settings.

Keywords: Collaboration, children, computers in education, tangible interfaces, augmented paper

INTRODUCTION

Previous research has shown that the standard PC set-up poses difficulties for collaborative work with much effort involved in coordinating and sharing the activities (Inkpen et. al. 1997). As an alternative to the standard set-up Inkpen explores the use of two mice to control a single PC. However, the results reveal a highly structured collaboration process. Indeed Inkpen's study focuses on the 'turn-taking' protocols children adopt, since they cannot both 'drive' the system at the same time. There is evidence for value in supporting children in moving freely between independent and collaborative activities. Steward, Bederson and Druin (1999) describe children's preference for a system with multiple input devices, Kidpad, over a standard system with a single mouse. The fact that this system did not enforce collaboration at all times was advantageous. Stanton et al. (2002) comment that the problem with a set-up such as Kidpad is that although two or more users may be able to work at the same time critical actions such as navigation can still only be carried out by one user at a time, furthermore to share the output device children must cluster around one immobile screen.

What has perhaps been overlooked is the value of paper and books for collaborative activities in educational environments. There have been a number of studies that have shown the importance of paper in office environments, where the flexibility and tangibility of paper enable us to absorb and use the information effectively (Sellen and Harper 2001, Luff et al 1992). These studies have also shown that paper is particularly good at supporting collaborative activities. Augmented paper has been proposed as a method of integrating paper and digital media combining the best of both. Previous research into augmented paper solutions has shown it to be beneficial in a variety of contexts. For example Listen Reader (Back et al. 2001) explores the use, in a museum context, of a book augmented with audio, triggered by RFID tags embedded in the pages. This study shows that the book held peoples' attention, but it does not describe the reasons for its apparent success, or the detail of the activities which took place. Stanton et al. (2003) describe how paper works as 'glue' when used as a portable recording method, as it can provide a bridge between a variety of other digital activities.

In this paper we describes the results on collaboration from a pilot study which explored children's use of augmented paper in contrast to a traditional paper book and a CDROM on a standard PC set-up. To create the links between paper and digital media we used visible barcodes printed on paper with a swipe wand to call up digital content on a laptop. We chose this technology for its technical simplicity, as it was intended to feed into the development of a more sophisticated technical solution which allows the user to call up screen-based information by touching anywhere on the paper with a sensing device (Luff et al 2004). The overall study including the details of technology used is described in Frohlich et al. 2001.

STUDY PROCESS

This pilot study compares the experiences of 6 pairs of 10 year old children using three different media formats to complete the same tasks. In order to present children with separate but similar paper and screen-based materials, we selected the *Encyclopedia of Nature* from Dorling Kindersley, which is published in book and CD-ROM formats. The augmented paper booklet was based on a subsection of the printed encyclopedia and excerpts from the CD. Barcodes were added to the booklet pages which, when swiped with a barcode reader, brought up associated digital sections from the CD. A variety of associations were chosen to reflect a diversity of possible data types such as audio, video, graphic animation, text and images. These data types were also used to cover a diversity of semantic links such as definitions of terms, expansions of the text, examples, and explanations.

The CD-ROM was used on a laptop with an external mouse attached. The augmented booklet was used with the laptop displaying associated content; the external mouse was removed and replaced by a barcode sensor wand. The children worked in pairs sharing access to each media format. Half of the children used the encyclopedia in book form and the other half used the CD-ROM, before transferring to the augmented booklet. Each pair was asked to complete a series of three tasks in each medium, expressed as a series of questions that the children had to answer. Questions were chosen to reflect three different kinds of reading, adapted from Adler et al. 1998: searching for a fact, comparing between alternatives, browsing for interesting items.

We then invited children to design their own augmented book pages. This was done by sticking a double-page spread on Seabirds from the Encyclopaedia onto a flipchart page, and giving children pens and stickers with which to annotate it. Children were asked to draw around regions of the printed pages to indicate active areas that might be ‘scanned’ for extra information, then to draw lines out from these areas where they could describe the extra information in words.

We collected and analysed video-recordings of their activities as they completed the tasks, enabling us to closely examine the children’s behaviour. This is a particularly valuable approach as it is often difficult for subjects, particularly children, to articulate their behaviour and reasons for it. Using the video we firstly made a detailed index of activities, identifying routine activities and recurrent problems. Then a number of excerpts were selected and the actions and conversation of the participants were transcribed in detail. Semi-structured interviews were conducted with both children at the same time after each stage of the test process. Their responses were also recorded onto video tape for analysis.

FINDINGS

CD-Rom laptop and mouse

Confirming the results of previous studies, when using the CD-ROM and laptop one child often spent a large amount of time waiting passively while the other child interacted with the CD-ROM, and there was a sharp division in the way tasks were divided up and executed.

The position of the screen and mouse affected the children’s access to the information. The laptop was rarely moved during the session, and was usually located in front of one child, who used the mouse and had better access to the information shown on the screen than the other. Some pairs of children attempted to share the laptop and mouse more equally, with mixed success. Pairs 4 and 6 began with the laptop placed between them giving both children good visual access to the screen. However this meant that the child without the mouse in those pairs had to lean across and into their partner’s desk space if they wanted to reach the mouse. This caused Fabian in Pair 4 to stand up for long periods during the session in order to be able to reach the mouse. Hattie and Ellie in Pair 6 also moved the mouse and mouse mat into the center of the table, where Hattie used it left-handed—despite the fact that she is right-handed. Pair 2 swapped seats half-way through the session in order to switch tasks. As a consequence of these problems the children tended to assume separate roles in completing the activities: navigating the CD and writing. This often resulted in one child passively waiting for the other child to complete an activity before they moved to the next task. For example when Sophie and Grace in Pair 2 were creating questions, Grace had browsed to information from which she formulated a question. Having conveyed this question to Sophie, she waited, arms folded, as Grace wrote down the question and answer.

What was also notable is that the distinct roles in the activities seemed to initiate more discussion between the children as to how approach the tasks. For example, a child with the mouse might explain to the other child what they intended to do next, and the other child would respond to this with other ideas about this course of action and at times the child without the mouse would dominate the decision making process through their verbal directions. In this session the children discussed actions that seemed to be achieved without explicit discussion when using the book.

Book

The children exhibited a wide variety of subtle physical actions when using the reference book e.g. pointing and holding a finger on the page to mark an item. Most often, pointing was used to identify an item of interest for the other child. Once an item of interest was identified, the children tended to keep their fingers next to an item as they examined and discussed it. Throughout the tasks the children were constantly repositioning the book. They usually began with the book placed between them. However when the tasks changed or the children swapped roles in an activity the book was moved to accommodate the shift in activities, e.g. pushed towards the back of the table to make room for writing. In order for one child to get a better view, the book was sometimes temporarily moved or tilted. In one instance a child used the book to draw the other back into the task by pulling it closer and tilting it up towards the other child. The analysis also revealed examples where a child would use their hand (or arm) to frame a piece of information for the other child to reference while they copied it onto their answer sheet or used it to construct a question. Often the children physically guided each other through pages and through items on a page. The children frequently searched for the same item together, sometimes literally turning pages together. Sometimes one child would instigate a search, and the other child would join in and take-over. In turning the pages together, joining in on actions, they demonstrated tacit agreement on the current activity.

Although the children often worked simultaneously on the same thing, they would at times work independently, in parallel, focusing on different items on the same page. They would also read items on different pages at the same time. Sometime a child would browse or even navigate to an item in a section of the book while the other read an item on another page. What is particularly notable is how the paper was used to coordinate their transitions between independent exploration and collaborative activity. We observed cases in which a child would mark a page with a finger or hand to return to later, in order to view and discuss an item on another page. The children were often aware of the other child's state, by *feeling* the other's actions through the book and knowing roughly what the other was doing. In an example where children are searching for a particular item we can see how they make subtle shifts between independent focus and collaborative activity as they attempt to resolve a difference in opinion. The two children, Ian and Lydia, are using the encyclopedia to find examples of birds that eat insects. They are having a disagreement about whether ducks, geese and swans are birds or not. Ian has turned to the section on these birds, and is looking for an example on the right hand page. Lydia, unconvinced that these are examples of birds, looks over the page on the left and attempts to attract Ian's attention, pointing out the title of the page 'Ducks, Geese and Swans' with the thumb of the hand with which she is holding the page corner, and saying "Look Look, Oi". Ian does not look over, as he has found a candidate solution and says, "Oh here… there. Yeah, and insects." Lydia interrupts Ian, looks at him and says, "Yeah, no sh sh, Ian" while still holding the corner of the page. As she says this Ian pulls the book towards him and places his left hand down on the right hand page. However this time Ian does looks over and Lydia reads out, "Ducks, Geese and Swans", and as she finishes she flips her hand under the left page she is holding up, ready to turn back to view other pages. Ian then looks back and pointing at the right hand page says, "But look, diet, may eat shellfish, and an ins-" and as he says this he moves his left hand onto the left page being lifted by Lydia in order to restrain her turning motion. At this point, there is visible tension down the centre of the left page where Lydia holds up the page corner, and Ian holds the page down (See Figure 1). Lydia tells Ian, 'Yeah but that's a duck not a bird', but as she does so she releases the tension in the page. Then Ian removes his hand from the page, looks over, and shifts to flicking through further pages in the section to explore and test Lydia's notion, saying 'Same thing en it?'.

Figure 1: Ian holds down the page while Lydia holds up the corner, with tension transferred through the paper

This example shows children shifting easily between their independent focus and collaborative discussion, where they can feel changes in the other's intentions through the paper, exploiting the physical properties of the book and its pages in tacit communication. When completing tasks using the book it was clear that in comparison to the CD both children were occupied in activity more of the time. Moreover, the children tended to be equally occupied and both contributed to all the activities involved.

Augmented booklet, laptop and wand

The augmented booklet enabled the children to share the tasks and activities evenly and flexibly, as with the book. Even though the children could only access the digital information with the wand, the book was still passed between them to access the information on paper, and the wand was frequently passed between the children and was shared more easily and more often than the mouse. The booklet also enabled the children to perform separate activities in parallel, as with the book. The digital information provided a further site for information, which could be used by one child, while the other browsed the book (see Figure 2). The only problem with this activity occurred when the child browsing the book triggered a clip which replaced the information the other children was using on–screen. The children often had difficulty swiping the barcodes to trigger the clips, since the technology itself was not very robust. However children often helped each other to trigger a barcode, taking it in turns to have a go and sometimes even holding the wand together as they swiped (see Figure 3).

Figure 2: Parallel screen and paper use.

Figure 3: Joint use of the barcode wand

In another example the children are creating a quiz for their parents, and have been looking for information from which to create questions. Ellie is writing down the answer to a previously created question, and Hattie drags the booklet towards her and flicks through a few pages. She stops on a page, and pulls the wand towards her and swipes a barcode. At the 'click' sound of the link being triggered Ellie looks up at the screen and narration from an audio clip begins. They listen for a while, and Hattie suggests a question. This is ignored by Ellie, however, and as Hattie goes to trigger the clip to begin the narration again Ellie takes the wand from Hattie and swipes another link. This brings up some text, from which Hattie then suggests a new question, which they agree on. Ellie's action here, where she takes the wand, may be based on their previous experience with finding information difficult to extract from narration that they cannot pause and rewind. Although there is some conflict between Ellie and Hattie in this example, it is their ability to both interact with the media at the same time, and with equal access, that makes this a constructive experience in which they are both engaged.

In interview, we found that the time-based and dynamic media made both the CD and the augmented booklet more compelling than the book. A strong preference was expressed for spoken content in which the screen-based information was read aloud. Their preference for a range of not only time-based but interactive media became clear during the participatory design session. A content analysis of all the links generated revealed that in addition to reading aloud text and providing rich media explanations, associations were used to bring static images to life, illustrate processes, hear and compare sounds, and change perspective on printed images. We found that children often used video to visualise some action suggested by an image or diagram mentioned in the text e.g. a picture of a puffin with fish in its mouth prompted several pairs to design an associated video clip showing how it caught them. Textual descriptions of processes often led the children to ask for a visualisation in video or an animated series of pictures. Ambient sounds were requested with most video clips together with narration, but also on their own e.g. to express bird calls. Also several children linked pictures to other pictures or video in order to achieve the effect of rotating or zooming in on the printed image to get a better view. This technique was used on the guillemot eggs to inspect egg markings, and on various seabird images to see other parts of their bodies.

The study also revealed flaws in the particular instantiation of augmented paper, and potential issues for the creation of successful designs in this mixed medium in the future. For example children complained explicitly about the difficulty of predicting what information would be triggered from a barcode, problems arose from both the unknown nature of the information content and from the media type itself, and when children were searching for information it was not clear to them where they should look, since there is no obvious distinction between the type of information in the book and the laptop. Full details of the problems can be found in Frohlich et al. 2001.

Overall performance

All pairs managed to answer the factual questions correctly within the given time. The groups differed only in the number of quiz questions they generated. An average of 5 questions was generated with the CD-ROM, whereas an average of 3 questions was generated with the book or the augmented booklet. Insofar as this reflects efficiency on the task, then the CD-ROM can be said to be slightly more efficient. However, the questions devised using the book and the augmented book did seem more creative. When constructing the quiz for their parents the children accessed a broad range of information from the book, in which there was no hierarchical structure restricting the *access* to the information. The children tended to browse more and sometimes used previously unrelated information to help them achieve their tasks e.g. when writing the false answers for their multiple choice questions the children spotted facts related to other animals and used these to create convincing alternatives to fool their parents.

CONCLUSION

The physical dimensions of the book and the material qualities of paper afford a diverse range of actions. It is this broad range of physical interactions that enable children to fluidly coordinate their actions, perform both collaborative and individual activities in parallel and make easy transitions between these two modes of working. The ergonomics of the book enable more equal access to the information than with the laptop and CD-ROM, and children spent less time inactive overall. We can see the same qualities in their use of the augmented booklet, the paper booklet can be browsed while information is used from the screen, and the wand can be easily shared. In the participatory design session it became clear that the digital media should be dynamic and interactive, and can bring to life the media represented in the booklet, truly 'augmenting' the information on paper rather than just adding to it. Returning to the augmented paper prototype we see that it could provide the flexibility of paper, and aid integration of digital media into paper-based activities. However, this study has alerted us to a variety of design considerations e.g. it must be clear from the paper information what will be found in the digital information, to enable easy navigation from paper to digital and back. We suggest that the problems and solutions for designing in this media can be easily understood by adapting the basic rules of interface design (e.g. Norman 1998). We believe this study shows compelling evidence for further studies into the use and value of paper, and paper augmented with digital media, for collaborative learning. There are now a variety of technologies that are more adaptable and flexible than the barcode technologies used here, and augmented paper is a practical and accessible means to effectively integrate digital media into educational environments now.

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A Heterogeneous Animated Platform for Educational Participatory Simulations

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Abstract. This paper describes a multi-user interactive installation featuring real time animated creatures and a mobile interaction paradigm. This paradigm has been designed to serve as a platform for education in a variety of content domains. Drawing on previous research in mobile computing and animated educational systems, this project contributes a novel metaphor for interactions among real and virtual creatures and worlds. This "Land/Water" metaphor offers that virtual space is like land for virtual creatures, and real space is like water for them. The interaction paradigm involves groups of animated creatures that live on desktop screens, and may be transported from screen to screen by means of mobile Tablet PCs carried by human participants. This paper presents a working implementation of this paradigm and describes its use as an educational tool.

Keywords: Human-Computer Interaction, Handheld/Mobile Devices, Virtual/3D Environments, Participatory Simulations

INTRODUCTION

The continual development of new computational technologies presents the opportunity for the creation of novel modes of interaction that may contribute to educational processes. Computer graphics have been embraced by the educational community in a wide variety of domains such as chemistry (Wilson, 2002) or history (Jenkins, 2002). More recently, mobile computational devices have begun to play a role in education through participatory simulations, e.g., (Klopfer & Woodruff, 2003), and university campus deployments, e.g., (Tatar *et al.*, 2003). This paper presents an interaction paradigm that embraces both computer graphics and mobile devices in an educational context and describes a working implementation of this paradigm. This interaction paradigm and implementations based on it offer a viable platform for presenting a range of educational content areas in a compelling interactive way.

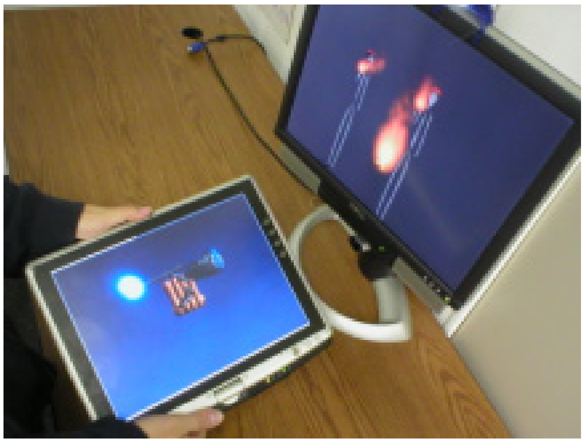

Figure 1: The Virtual Raft Project. Desktop screens serve as "virtual islands" and tablet PCs serve as "virtual rafts."

The interaction paradigm presented here is a multi-user experience involving several fixed computer displays and several mobile handheld devices (see Figure 1). Each fixed display serves as a "virtual island" inhabited by populations of 3D animated virtual creatures. When a human participant brings one of the mobile devices (a "virtual raft") close to the screen, one of the creatures on the virtual island moves onto the virtual raft. The participant may then carry that creature to a different virtual island; once the raft is close enough to the other island, the creature can move off the handheld onto the other desktop screen. This interaction paradigm, where people participate in the migration and dispersal of individuals and populations, encourages an active engagement from participants in the unfolding of the natural or cultural history existing on the islands. This interaction may serve as a platform for a range of educational content, including anthropology, social science, mythology, ecology and environmental biology (such as the study of biodiversity or invasive species.) For a better sense of the interaction, please view the following short video:

`http://www.ics.uci.edu/~wmt/movies/HomeschoolVideo.mov`

The core metaphor in this interaction paradigm draws a parallel between the land/water distinction in the real world and the virtual space/real space distinction. In this "Land/Water" metaphor, virtual space serves as land for virtual creatures, and real space functions as water. Virtual creatures may move around in virtual space, but are not able to move around in real space; similarly, real land animals are able to operate effectively on land but not nearly so well in water.

This metaphor provides a set of organizing principles for an interactive educational simulation. It distinguishes the operational domain of virtual creatures from that of people, thereby providing a way of explaining how people are meant to interact with the system. It provides inspiration for subject matter that may be effectively conveyed through this kind of simulation. And it provides guidance for the visual, acoustic, tactile and other elements of the interactive experience. While the platform is not ideal for all topics of education, it does provide a useful framework for exploring topics that deal with groups of people (e.g., social or cultural education, see Figure 2), groups of biological organisms (ecology, evolution, etc.) and potentially other topics (math, languages) as well.

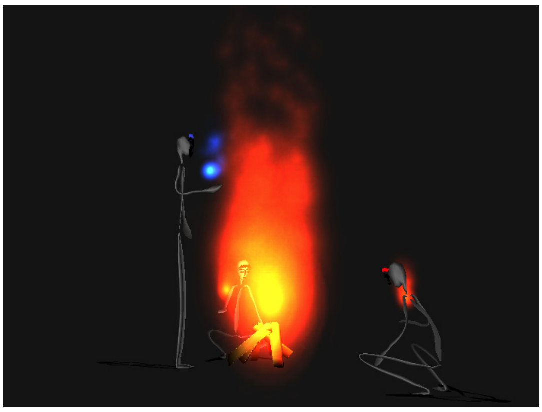

Figure 2: A community of autonomous animated characters inhabits each virtual island in one version of the system.

RELATED WORK

This project builds on previous work in educational technology in two main areas. The first area, computer graphics and animation, has a long history of engagement with education. Computer graphics have been used to teach chemistry by visualizing molecules (Wilson, 2002), astronomy through collaborative virtual reality (Hay et al., 2002), history through interactive history-based games (Jenkins, 2002) and many other topics. Animated characters are becoming common in education and training simulations, e.g., (Hill *et al.*, 2003). Affective characters, in particular, are also being used to help the educational process (Schaub *et al.*, 2003). The system presented here offers graphics that are competitive with the high end of modern computer games, using 3D autonomous characters, real-time shadows, and particle system fire and water effects.

Mobile computational devices are also on the rise in the popular cultures of industrialized societies, with the rapid penetration of cell phones and PDAs over the last few years. Numerous researchers have considered the capabilities of these mobile formats in educational contexts, e.g., (Roschelle & Pea, 2002). The Teacher Education Program at MIT has done pioneering work in developing participatory simulations (Klopfer & Woodruff, 2003). Other researchers have explored the use of mobile devices in education through a variety of different platforms (Borovoy et al., 1998). The project described in this paper uses mobile devices with high end graphics and built-in accelerometers (sensors for detecting the motion of the device); the use of these capabilities helps to create a novel mobile interaction with believable autonomous characters and virtual worlds, and distinguishes this work from previous research efforts.

This project also builds on previous work in autonomous characters and interactive installation design. The system extends a code base developed by the author and his collaborators, e.g., (Isla *et al.*, 2001), and incorporates ideas in believable characters (Perlin & Goldberg, 1996), affective computing (Picard, 1997) and biomorphic computation. By synthesizing elements from each of these areas, the project presented here offers a unique and novel educational interaction.

INTERACTION PARADIGM

A challenge in building virtual environments is deciding how real space and virtual space should relate to each other. An effective way to present the virtual/real boundary is to offer a metaphor that gives people a starting point for their understanding. For example, the metaphor in a flight simulator is that the user is a pilot sitting in the cockpit and the computer screen is the front windshield of the airplane. Other computational metaphors suggest that the computer screen is a “desktop” and that areas of the screen are “windows.”

The central metaphor presented in this paper draws a parallel between the virtual space/real space distinction and the commonly understood distinction between land and water. This core “Land/Water” metaphor has served as the primary focus in developing all elements of the interaction paradigm and has had numerous implications for the design of the system. The core elements of the interaction paradigm are: animated creatures, virtual islands, virtual rafts and human participants. This section addresses each of these elements in turn.

The goal of this interaction paradigm is to provide a way for human participants to engage with animated creatures. These creatures provide the central focus for the educational content to be delivered by the system. Each stationary computer screen provides a fixed window onto an island community inhabited by the animated creatures. The screen itself serves as the boundary between virtual land – the area where the virtual creatures live and that people can see – and virtual water – the “gulf” of real space where people live and virtual creatures can not go. The animated creatures are constrained to exist on a virtual island, but are able to look out over the virtual water and interact with things they see there (by means of a web cam mounted on top of the screen).

While the virtual islands allow people to have some simple interactions with the virtual creatures via the web cams on each island, the primary mode of interaction is through several Tablet PCs that people carry around the installation space. These Tablet PCs serve as virtual rafts that are able to carry creatures and interact with the islands and with each other. Each raft has a water simulation running on it, with simple real-time waves and an animated wooden platform in the middle of the screen (see Figure 3). The Tablet PCs have two-axis accelerometers built into them, which provide information about how the device is moving. These accelerometers make it possible for the character to react when the participant tilts the device. This simple mode of interaction, where the virtual raft responds to real world gravity, creates a strong link between the virtual and real worlds.

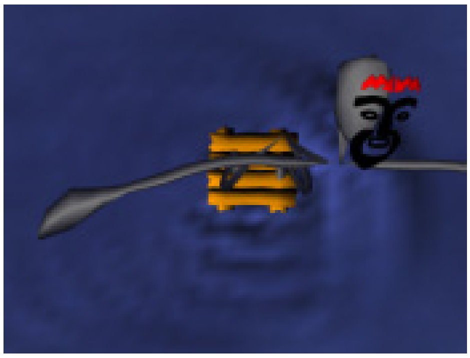

Figure 3: A view of the screen on the tablet PC based virtual raft.

This interaction paradigm is designed to situate human participants at the conceptual center of the installation. People use the rafts to help characters move onto new islands; in this regard, the participants serve the role of an ocean current or other force of nature. By putting people in a position to move creatures around the world and view the ensuing results, the project seeks to enable an active engagement with the ideas presented by each installation. This centrality of the participants will be particularly important in the upcoming ecology-based version of the project (see Future Work section below), which seeks in part to demonstrate that environmental stewardship is an active, hands-on process.

PLATFORM FOR EDUCATION

The virtual raft interaction paradigm has been designed to help people have interactive educational experiences. Storytelling, and in particular interactive storytelling, have been used effectively as learning tools (Rossiter, 2002; Roussos et al., 1997). The Virtual Raft paradigm provides many of the ingredients of good stories – characters, voyages, encounters with different kinds of creatures – and thereby encourages people to find stories in the events that they find there. By giving participants the raw materials of stories, the project lets them to create their own narratives through which they can assemble an understanding of the material presented.

The paradigm also provides a fertile platform for providing a range of educational content. The current installation has been developed with humanoid characters as a means for addressing color theory, social content and mythology. Another version is currently bring planned in collaboration with the Discovery Science Center in Orange County, CA, that features animated versions of several animal species and may be used to help students learn ecological concepts such as the spread of biodiversity and the impact of invasive species.

The value of this paradigm comes not just from its ability to be adapted to a range of different content domains, but also from its ability to encourage people to engage in critical thinking. The system does not necessarily prescribe a certain set of ideas, but instead allows participants to interact with a system and discover for themselves the effects of their actions. While the computational design of each implementation will determine the cause-and-effect relationships to which participants will be exposed, the value judgments may be left to the participants themselves.

This paradigm also encourages participants to engage in real-time problem solving. Each version of the system has a multiplicity of outcomes based on how people interact. The design of the system allows people to try out certain solutions and then attempt to change the impact that they have had. While people's actions are effectively irreversible, there is nevertheless an abundance of opportunities to recover from previous actions. By combining the irreversibility of action and the potential to recover from mistakes with multiple user-defined opportunities for "success," the system encourages an active engagement with the concepts being presented.

EVALUATION

A fully functional prototype based on this paradigm was created in summer 2004. This prototype was exhibited at the opening of a new building on the campus of the University of California, Irvine, in November 2004. Approximately 200 participants interacted with the installation over two days, in nine groups of 20 and several small groups. These participants included industry professionals, academic administrators, professors, college students and a few grade school children. Each group visited the installation for a total of ten minutes. This visit consisted of a two minute introduction to the overall research, a one minute orientation to the installation itself, a five minute interaction with the installation, and two minutes for questions at the end. While it was not possible to collect data through questionnaires or other experimental instruments at this event, the video cited above offers some first hand evidence that the installation had the impacts described in this section.

The focus of this installation was to teach participants how the colors of light blend together. When each group of participants arrived, the three islands had red, green and blue fires on them, and each of the islands was inhabited by three characters with torches the same color as the fire. Whenever a character moved to a new island, it would walk over to the fire on that island and add its torch color to it. Therefore, if a participant carried a character with a red torch to a green island, the red character would walk over to the green fire and the fire would turn yellow. The participants were assigned the task of using the three rafts to disperse the characters so that each island ended up with white fire on it. To accomplish this task required at least six successful character transmissions (a character with a red torch needed to go to the blue island and the green island, a blue character needed to go to red and green islands, and a green character needed to go to the blue and red islands).

All nine large groups completed the task of turning all three fires white within the allotted five minutes. In the course of observing 200 people interact with the installation, several hypotheses about the system were drawn. First, the success of all nine groups supports the idea that the interaction paradigm draws on a metaphor that people readily understand. Since each group was able to perform the assigned task after only one minute of introduction to the interaction, the island/raft interface appears to be intuitive. People of all ages were willing to carry the virtual raft interface and convey characters around the space. While 200 people mostly from southern California does not represent a cross sample of humanity, it did appear that the installation did not rely upon a given language or cultural perspective for the core interaction paradigm to retain its effectiveness.

Second, since people took turns carrying the interface, the paradigm is transferable and lends itself to cooperation among multiple users. Whereas many mixed or augmented reality environments require some sort of tethered interface such as a heads up display or data glove, this interaction paradigm allows people to move fluidly in and out of the role of primary interactor without any significant changeover cost. The multi-user aspect of the virtual raft system caused the groups to work together to accomplish the task, including both raft-holders and bystanders. It was common to hear exclamations such as, “Ooh, this island has a yellow fire, so it needs somebody with a blue torch!” and to have people share information with each other about where characters of various colors were in the space

A third feature of the system is that the interaction appears to be engaging to people. When each group, which had been through an hour of speeches and were now at the end of an hour-long tour of projects, reached the installation space, they were largely quiet and subdued. However, once the interaction with the Virtual Raft Project began, they became much more animated. During the five minute interaction, members of each of the groups talked and interacted physically with each other. At the end of several interactions, when the group accomplished its goal, the participants broke into spontaneous applause. This applause was not directed at the people demonstrating the project, but rather at the group itself for succeeding at its task.

Figure 4: Multiple participants may interact with the installation simultaneously by means of several virtual rafts.

FUTURE WORK

This project is developing in two main directions. First, this system could be used as a platform for exploring and learning about social and cultural phenomena. Themes such as the spread of cultures, acceptance/discrimination, communication and teamwork could all be addressed by means of a system in which characters encounter communities that are new to them and try to find their place in that social system. In order to develop these facets of the system, it will be necessary to build a more comprehensive system of social intelligence in the characters. Previous work by the author has focused on social intelligence in virtual wolves (Tomlinson, 2002), and will provide a starting point for human-like computational social competence. In particular, mechanisms for characters to remember information about their world and to communicate this information to each other will be important parts of this future implementation.

The research team that created the Virtual Raft Project is also currently in the design stages for a version of the system based on ecology. By letting people move animated species among several virtual islands, the installations will allow them to understand concepts such as the spread or contraction of biodiversity, the role of predator/prey interactions, and the impact of invasive species. This project is being designed in consultation with educational curators at Discovery Science Center in Orange County, CA. The creators are developing it with an awareness of the California Science Standards (in particular focusing on the life sciences curriculum); the system will be evaluated based on its effectiveness at helping visitors learn that content. In order to be exhibited in a science center, it will be necessary to make the mobile elements of the system more robust to handling by thousands of children every year. In addition to producing a California specific installation, the system will be designed to produce a series of regionally specific installations featuring species from a range of regional ecosystems. By designing the system from its inception to develop multiple versions, the research team hopes to make it significantly easier to be able to develop new bodies of content for the same core interactive platform. The broad goal of the project is to give visitors to regional science centers and museums an opportunity to think critically about the science of ecology by engaging with locally relevant ecological themes in an interactive setting.

CONCLUSIONS

This paper has presented a novel interaction paradigm for multi-user participatory simulations. This paradigm involves desktop computer screens that serve as virtual islands populated by autonomous 3D animated creatures, and mobile devices, such as tablet PCs, that serve as virtual rafts that participants may use to carry creatures between the islands. This paper described how this "Island/Raft" paradigm may serve as an interactive platform for education in several different content domains, and presented a functional implementation of the paradigm.

This paper and the research it represents contribute to a new generation of educational systems that draw on technological advances in mobile computing, ubiquitous computing, computer graphics and artificial intelligence, and compete effectively against emerging forms of interactive entertainment. By harnessing these technologies and drawing elements from entertainment media to create an engaging experience, computational systems will be able to present content in ways that are of interest to learners and growing effectiveness as educational tools.

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The Effect of Video-Augmented Chat on Collaborative Learning with Cases

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Abstract. Efficient learning with cases requires discussion on the facts of the case as well as on their meaning. We investigated the focus (factual vs. abstract) of a case-based learning discussion when video was added to a chat-based learning system. Students whose first experience includes high-quality video, focus significantly more on abstract knowledge than students first exposed to chat-only or chat + low-quality video. We also found that these students expressed a preference for face-to-face discussion. We conclude that video may improve learning where discussions on abstract *and* concrete knowledge are important.

Keywords: case-based CSCL, video, eye tracking, dialogue analysis, non-verbal communication

INTRODUCTION

Anthropological and social research has consistently revealed the importance of non-verbal cues for dialogue, discourse and information management. However, the specific effects of these additional cues on learning are not well studied. Here we investigate the availability of visual contact on learning by analyzing a case-based CSCL dialogue, distinguishing between foci on factual information and foci on abstract, general knowledge. Good learning with cases requires that generalizations are drawn from the factual information conveyed in the cases and that the point of the case is understood and reflected upon (Guzdial, et al. 1996). While this research has been carried out in a case-based CSCL environment, its findings are relevant for all educational methods using discussion where a careful balance between factual and general knowledge must be fostered.

BACKGROUND

The effect of non-verbal cues on dialogues is well studied. For example, focus shifts are introduced and accompanied by specific facial behaviors and gestures (Kendon, 1987; McNeill, 1992); establishing and maintaining common ground uses non-verbal cues (Chovil, 1991; Argyle & Cook, 1976). Less is known about how visual cues affect learning quality and efficacy. Some pertinent research has, however, shown that the technology used for learning affects what is talked about. For example, Veerman et al. (1999) found that in chat-only systems, students focus more on the use of knowledge than its meaning, while the opposite result is found in a system featuring chat and a facility for representing of conceptual knowledge. The student writing groups of Hewett (1998) using computers and oral communication focused on more abstract, global idea development, than their peers using only computers. And in observational studies of learning with cases comparing f2f with CMC, from which this study derived its hypotheses, Tscholl & Dowell (2005) found a similar pattern. The alternative explanation of differences on learning with and without visual contact focuses on the improved intimacy and immediacy of face-to-face dialogues. A certain amount of intimacy is valuable in case-based learning, where drawing parallels and seeing similarities and differences between (personal) episodic knowledge and the case under discussion is an important means of generalizing. Further, as collaborative learning is promoted by exchanging viewpoints, contrasting and critiquing, the closeness of visual contact may affect the dynamic of the dialogue (cf. Walther (1999))

Augmenting chat with a video channel may be a straightforward way to counter the downsides of chat alone. This research aims to contribute to the understanding of the impact of video on learning discussions.

RESEARCH QUESTION AND APPROACH

The primary research question was whether the addition of a video channel leads to more discussion of abstract concepts. More generally we were interested in whether the dialogue patterns differed across the media conditions. We this by using two different video conditions, alongside chat only communication. In the *low frame rate* condition video was delivered at 1 frame every five seconds. This frame rate was adopted to give a sense of presence of the other students while effectively blocking non-verbal communication. As outlined recently by (Ehrlich et al, 2000), motion is an important pre-requisite for emotion communication, but at 1 frame very 5 seconds no motion is communicated and simple non-verbal gestures like nods and shakes of the head cannot be discriminated. In the *high frame rate* condition video was delivered at 25 frames/second. To measure how students used the video channel we employed eye tracking. We also measured user perceptions of the different media conditions with a short questionnaire.

Dependent Variables

Facts vs. General (F-G Coding)

We distinguished two types of foci: concrete foci, includes facts or detailed aspects of the case, and the other, abstract foci, includes general concepts pertinent to the case, the principle or the 'point' of the case. What we wanted to capture with this distinction is whether an utterance is explicitly tied to the factual information conveyed in the case or whether it is only derived from it and positioned into the dialogue as a stand-alone object of discussion. We reasoned that bringing such objects into the discussion would require non-verbal communication, as such a shift would entail a change to, and maintenance of, a more complex topic.

All utterances or propositions within an utterance containing at least one reference to a specific detail of the case or the case as a whole ("but she refused to attend twice") were counted as *concrete/factual (F).* Utterances focusing on the definition or 'nature' of concepts ("what is negligence actually"), utterances referring to the general consequence of applying a concept to the case ("…but then a doctor has to check every symptom every time. This is not practical"), and utterances mentioning the point of the case ("this is a he-said, she-said situation") were designated as *abstract/general (G).* Utterances outside these criterions (such as "yes, I think so, too") where categorized as the utterance they referred to (if the reference could be determined uniquely).

Coordination measure

We measure coordination by assigning a score of 0, 1, 2, …to indicate the number of messages between the current and the topically related one. Messages starting as new thread were scored 0.

Eye-Tracking Measures

The eye tracker records gaze position on the screen 50 times/second as a series of X-Y data points. To understand where people look during the discussion we categorized the screen into 4 Regions of Interest. These were, (i) the participants' thumbnails, (ii) video focus window, (iii) chat window and (iv) the browser containing the learning material. An illustration of these regions and the layout used in the evaluation is shown in Figure 1. The measure of *Gaze %* is the proportion of (raw X-Y) gaze samples that are recorded in different areas of the screen. As an indicator of transitions we also recorded the *Revisits* to the different regions. A *revisit* is counted when gaze moves briefly out of one region for a single fixation before returning back to that region. It has been associated with the need to seek additional information.

Questionnaire Measures

The short questionnaire with 8 questions was structured as a series of statements, gauging for usability, enjoyment and perceived video quality. Included was: "I would have preferred a face to face discussion". After discussing each case participants rated their strength of agreement with the statements on a 7-point scale.

E-LEARNING STUDY

Groups of 4 students discussed three cases under three different media conditions: chat only, low frame rate (0.2fps) and high frame rate (25fps). The three cases were actual cases of medical negligence, including a short description of the case details and a judges' verdict (example: Figure 1). The task given was to explain the judge's verdict.

The **Vadera** case: A 22-year old woman presented herself 3 times within a year at her GP's practice, with the intention of starting contraception before she got married. She was warned that there were health risks associated with contraception pills. On the last visit her blood pressure was taken and it was at 150/100 (higher than normal for a woman of her age). This high reading was taken by the GP (Dr. Shaw) as a symptom of 'white-coat hypertension', a phenomenon cause by anxiety that occurs in a doctor's presence, that can however also be indicative of a general tendency to hypertension. The next day, she started the pill. A week later, the plaintiff was admitted to the hospital suffering from numbness and difficulty in walking. Her BP was read several times and was at 170/110, 110/60 and 140/110. She had suffered a stroke that left her completely paralysed.
The statistical evidence does not link taking contraceptives with stroke, over the population as a whole.

Verdict: the judge did find the GP **negligent** but **not liable.**

Figure 1: An example case from the study

Method

Participants

24 people participated in the study. 16 were female and 8 male. The mean age was 26. They were recruited from subject pools within UCL and were paid $15 for participation. They were tested in groups of 4 people. All groups conducted discussion of cases in all three conditions, *Chat Only*, *Low Frame Rate* and *High Frame Rate*. One member of each group was eye-tracked to understand their attention patterns.

Equipment and Software

For our experiments we used a modified version of Marratech Pro, a commercially available multimedia conferencing tool that includes media such as audio, video, chat and a shared whiteboard. The Marratech Pro client is used in conjunction with the Marratech E-meeting Portal (a license server and media gateway) to set up multimedia conferencing sessions. The version we used limited bandwidth usage for video to 400 kb/s.

Procedure

A short questionnaire given before the discussion probed basic demographic information and the participants' experience with chat rooms, instant messaging (IM) and video conferencing. At the end of each case discussion they completed a short questionnaire. The same questions were asked after each case and the questionnaire layout encouraged active comparison with previous responses. At the end of the session participants were given a final questionnaire to understand how they used the video channel and what they tried to communicate

Design

Two groups of 4 students were assigned to one of three different variations that counterbalanced the order of media conditions with a Latin Squares design (Table 1).

Order	Case 1	Case 2	Case 3
A (2x4)	Chat	Low (0.2fps)	High (25fps)
B (2x4)	High	Chat	Low
C (2x4)	Low	High	Chat

Table 1: Study design.

RESULTS

Dialogue Analysis

Figure 2 shows the number of general concepts recorded in the dialogue. As illustrated in the figure there were significantly more general concepts produced by the two groups whose first experience was high frame rate video ($Z=3.068$, $p< 0.001$). However, we found no difference in chat coordination between the different media conditions.

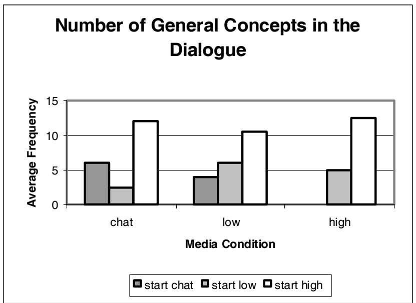

Figure 2: G's produced by condition

Questionnaire Data

Analysis of the questionnaire data also revealed effects contingent on the *order* in which media conditions were experienced. For example, students said they found it harder to speak their mind if their first experience had been with chat only [$F(4,42) = 2.7$, $p < 0.05$]. This difference disappeared when they used high frame rate video. Preference for a face-to-face discussion also interacted with the *order* in which media conditions were experienced. Those who were first exposed to high frame rate (25fps), expressed a clear preference for face-to-face discussion [$F(2,21) = 5.35$, $P < 0.05$]. By contrast, those exposed to the low frame rate (0.2fps) on the whole said they would not prefer a face-to-face discussion. Those exposed to chat first did not have an opinion either way.

Eye-Tracking Data

The eye tracking data illustrate that the video actually received very little of users' attention. A visualization of the gaze distribution is presented in Figure 3 (the learning material display occupied the right and center of the screen; below left: chat window; mid left: large video; above left: thumbnails). Gaze density is clearly much higher in the chat window. Surprisingly, in the video conditions less that 10% of gaze is directed towards the large video window and even less towards the thumbnail window. Across media conditions there appeared to be large differences in the *revisits* made to different screen regions. As described above, a *revisit* is scored when the eye makes a single fixation outside a region before returning to that region. Revisits to both the focus and chat windows are much higher in the high frame rate condition [$F(2,4) = 14.5$, $p < 0.05$; $F(2,4) = 7.56$, $p < 0.05$]. This indicates in the high frame rate condition there are many instances where a glance is made from the chat to the focus window and vice versa.

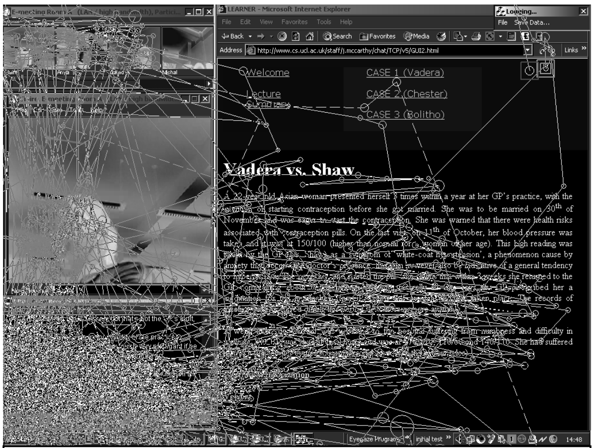

Figure 3: Gaze distribution.

One explanation of this result is that the eye is attracted to the motion in the high video condition. If this were the case, we would expect the eye to be drawn to the video immediately after it switches to the latest message sender. However, only 3% of all video switches were immediately accompanied by a glance to the video focus window. Much more common was that the student would first *read the message and then glance* at the focus window.

To investigate further, we conducted a post-hoc investigation of eye movements in the "Start high" condition. We were interested in whether the eye movements were related in any way to shifts in the dialogue from discussing facts to general concepts of the case. Specifically, the video may be used for checking the reaction to a sent message. To investigate, we calculated two different measures. One records the proportion of messages of a particular type that are followed by glances to the video window. The other measures the mean number of glances made in these instances. As shown in Table 2, there are a higher proportion of glances to the video window in the high frame rate condition. However, there is clearly no difference in the proportion of glances following factual (F) statements vs. general (G) concepts. In contrast, though not significant, the mean number glances following factual statements is marginally higher than those following general concepts.

	High Frame Rate		Low Frame Rate	
	F	G	F	G
Prop. Of messages followed by video glances	71%	73%	52%	56%
Mean No. Of Glances	2.3	1.8	3.4	1.7

Table 2: Glances during different phases of discussion.

As an additional analysis we calculated equivalent measures to investigate how they used the video window when they either sent a message themselves or read a message from someone else. One measure was the proportion of times they glanced at the video after they sent a message (to check response) vs. the proportion of times they glanced at it when someone else sent a message (to check intention). For the messages where they did glance at the

	High Frame Rate		Low Frame Rate	
	Sent	Read	Sent	Read
Prop. of messages followed by video glances	69%	70%	45%	63%
Mean No. Of Glances	2.3	2.3	2.8	2.6

Table 3: Glances to messages sent and read

video, we calculated the mean number of glances/message. Again however, we found fewer glances to the video window in the low frame rate condition but no differences in glances following messages sent vs. messages read (see Table 3). Expressed emotion during the chat sessions was almost completely absent.

CONCLUSIONS

The results show that adding high-quality video to a chat-based distributed learning environment has an effect on the discussion, attitudes and behavior of participants. However this was only observed when the students first used high quality video. Then, more general concepts in the discussion were produced, an effect that persisted through the remainder of the session. The eye tracking data show that compared to the chat window there were very few glances to the video focus window. However there was some evidence that people would frequently and briefly switch between the chat and video window, especially in the high frame rate condition. We found no evidence that the video channel was used in any way to regulate the dialogue. Even if such evidence were uncovered it would not explain the production of general concepts for the “start high” groups when they communicated by chat alone. Thus, although the video has had an effect, we find no evidence that this effect is due to a *regulation of dialogue* through the visual channel.

A much simpler explanation is that the first experience with high frame rate video changes the way students feel about each other. The video may increase the intimacy between students in the group. To some extent, this intimacy may be unfulfilled. Although students seek eye contact, because of the position of the camera, it is never actually made. This leaves them feeling as though they would do better to meet face to face. In other words, the first experience with high quality video may function as an *ice-breaker* - whose importance in education is well known (Lott & Lott, 1965; Meyers, 1997).

There are two innovations in this study that are fruitful for future research. Firstly, the technique to code concrete and abstract references in the dialogue revealed interesting differences that identify subtle changes in communication patterns under different media conditions. Secondly the use of eye tracking helps to isolate in detail how people use the information available on the screen.

While a coding that distinguishes between factual and general concepts is particularly suited to the *Case Based Learning* method we use here it can also be used in other approaches such as problem-based-learning On the eye-tracking front we would caution against using a simple measure of gaze % to different screen regions. As shown by the re-visit and post-hoc analysis the gaze % measure can hide subtle but important differences in how people use information available on the screen. Overall we would recommend adopting a multi-dimensional approach to identify how dialogue, attitude and eye data can be tied together to give a more detailed picture of user performance.

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CSC*: Computer Supported Collaborative Work, Learning, and Play

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Abstract. The authors combine their experiences in three independent studies of informal learning in the contexts of the workplace, school and leisure. They uncover aspects of collaborative work, learning and play involving the use of different learning and teaching techniques, and supported by appropriations of the regular use of the applications. The importance of play, both for application learning and innovative use in different settings, including the workplace, is examined. The implications of explicitly supporting ad hoc collaborative approaches to learning how to use a computer application are explored.

Keywords: collaborative help-giving, informal learning, workplace learning, play, CSCW

INTRODUCTION

Computer supported collaborative learning is not just applicable to formal school-based hour-long lessons. CSCL researchers can also inform the design and support of more ad-hoc collaborative interactions interleaved with other aspects of learning, work or play. This paper is the result of the three authors discovering quite by chance that they had each independently explored aspects of informal learning in three independent studies. After the studies had been completed and our data had been analyzed for our own independent purposes, we met together over several months, sharing and reflecting on our separate approaches, analyses, findings and interpretations. We found some intriguing parallels in the kinds of interaction observed in very different use contexts, as well as many differences, and this has provoked us to reconsider what we might investigate in the future in more depth in our respective contexts of interest. In this paper we focus on exploring the ways in which people collaboratively learn application use, the pedagogic techniques employed, and the way that the system in use is appropriated and adapted to support various kinds of activity. We believe an examination of application learning in different contexts can provide a useful cross-fertilization of ideas for the building in of functionalities and interfaces to afford different learning and teaching techniques. By the happenstance of independently having chosen to study contexts that can loosely be described as work, learning and play, we began to think about different pairings of the three concepts. In particular, we consider the way that the applications are used and appropriated in ways that their designers had not intended, particularly to allow more people to use them as a way of facilitating learning. We also consider the role that play may take in supporting learning, creativity and innovative application use, not just for young children, and not just in leisure or kindergarten or elementary school settings but also by adults in various settings, even including the workplace.

THREE DIFFERENT STUDIES OF COLLABORATIVE INTERACTION

The three studies had been developed independently using different methodologies and to some extent informed by different intellectual traditions (educational theory, psychology and computer science, with a further influence of ethnography on all three). It was only afterwards that the authors began to compare notes. We must emphasize the lack of consistency in approach between the three studies, caused by their independent nature. Although this weakens the opportunity for systematic comparisons, we believe it serves to reinforce the triangulation of the individual findings, outlined here and elaborated in separate papers. In all three studies we find learning embedded in other activities. In the workplace, the main focus of people is to get their work tasks done, but when problems are encountered, people ask colleagues for help and advice. In the case of playing a competitive console game, the main focus is to have an enjoyable time by competing, but if one's opponent is far less skilled than you are, you may need to help them learn enough to be able to have an enjoyable game. In interacting with peers and waiting one's turn to play a game in a classroom, children seem compelled to help each other improve.

Computer Supported Collaborative Play (CSCP): Students Playing Console Games

Twenty-four participants were recruited from a university educational psychology subject pool. Participants were asked to bring either one or two same-sex friends to the study. There were eight male and eight female dyad and four male and four female triad sessions. In each session participant groups played two different console games Tennis 2K2, a sports game, and Halo, a "first-person shooter" game. Half of the dyads and all of the triads played both of these games in competitive game play mode (against one another), and the remaining half of the dyads played both games in cooperative game play mode (in order to win the game participants had to work together). The 24 two-hour game play sessions were recorded using two video cameras one to capture the on-screen game play and the other to capture the facial expressions and gestures of the participants. This study (Hinn, 2005) was the most experimentally oriented of the three, actually taking place in a laboratory. However, substantial efforts were taken to create situations similar to game-playing scenarios that occur in people's living rooms.

Computer Supported Cooperative Work (CSCW): Informal Workplace Help-Giving

Several different workplaces were studied, including different departments of a large financial institution, a university library help desk and phone center, a university department, a design group of a large private manufacturing company, and an agricultural outreach unit. The approach used workplace observation and post-incident interviews. A few interactions were audio or videotaped. Informal help giving and collaborative problem-solving incidents were identified, coded and analyzed. Interviews asked about the episode from the perspective of the participants, the techniques used in resolving and explaining the problem, to what extent they 'solved' the problem, and whether it related to other episodes not directly observed (Twidale & Ruhleder, 2004). Other workplace studies have particularly focused on whom people ask. By contrast this study focused on what happened in the help-giving interaction itself, and the degree to which the software helped or hindered.

Computer Supported Collaborative Learning (CSCL): Children Around a Classroom Computer

A year-long study was conducted in a first-grade classroom in a public school. In this classroom, the students could use the classroom computers for work or games only during "choice time," between 2–3 p.m. from Monday to Thursday. During the fieldwork, the researcher visited the classroom an average of 2-3 times a week. Videos were shot of children in front of the two computers, Videotape, field notes, interviews and artifacts (including the students' computer work and log, the sign-up waiting list for the computer, and choice time log) were the main data sources. Interviews with all the students were used to gather the participants' views and perceptions of peers, computers and their interactions at the computer. Interviews with the teacher revealed her point of view of the class, peer culture and computer curriculum (Wang, 2003).

PATTERNS IN LEARNING HOW TO USE AN APPLICATION

Although the studies had looked at very different contexts of interaction with computers and applied somewhat different methodological and analytic approaches, the more we discussed our findings, the more we uncovered similarities, particularly in issues that relate to the process of learning to use an application. In all cases episodes occurred of collaborative learning of how to use a computer application. The extent to which it was computer *supported* collaborative learning needs more consideration, given that the applications were not explicit CSCL tools, but rather were ingeniously appropriated to temporarily support collaboration.

Appropriation for Use by More People than Designed

In all three studies, the number of people in some way using the computer is more than the applications were intended for. The applications may not have been considered to be CSCW or CSCL, but they were appropriated to be used as such. The resultant usage is a kind of Single Display Groupware (Stewart et al., 1999), a sub-field which considers interactions that occur when more than one person is using the same computer.

In the workplace studies, none of the typically used software (including regular office applications, databases, CAD systems, and web browsers) was explicitly collaborative. When a breakdown (Schön, 1983) occurred such as confusion about how to do something, the user may call on a colleague to help. Such situations are widespread and are widely reported in the literature (Twidale, 2005).

The console game study was lab based and so somewhat less authentic. Although have no data on how often more than two people are present when two player games are played in domestic environments, we do believe that it does happen, and that games designers might want to take it into account. Consequently, the study included both dyads and triads to enable the activity to be studied and compared to the 'proper' number of people. Many computer games include modes for individual play, for occasions when two players are not available.

The classroom only had two computers, and many children wanted to use the one computer that had the most popular games in the choice period. The teacher had created a set of rules to enable and enforce sharing of the computer. There was a signup sheet with five minute slots and a timer, and two chairs in front of the computer. The teacher declared that that the child sitting on the left was the official player (with a legitimate turn) and the child on the right was the official observer. When the timer indicated the end of the five minute timeslot, the child on the left would get up and the child on the right then moved over to the left chair while the next-in-line child took the right chair. Any other watching or waiting was not allowed (Wang, 2003).

However these teacher-imposed rules of conduct were subsequently modified by the children. The five minute transfers happened very rapidly and smoothly, with the game continuing throughout. The children minimized the disruption of the turn-taking process, since the child on the right was already involved in the game and was ready to carry on immediately where the previous child left off. Also, the waiting child was often already part of the activity by (illicitly) watching and commenting from a standing position, and so ready to take on his or her role as the right-seated participant. This saved the considerable overhead in a 5 minute turn of quitting and starting a new game or even a new game application. Effectively only one game took place during the whole session, with the children involved in different ways and degrees throughout, and collectively attaining far higher levels of progress in the game than if each child started from scratch. Children who didn't get a turn would often approach the computer corner and stay watching and playing with the seated player. To justify this they used a wide range of strategies: signing up or checking the waiting list, ostensibly doing their chosen activities in the carpet area next to the computer, and observing from distance and finding a right time to join by offering suggestions. The number of these additional ‘participants’ varied from 2 to 8 with an average of 4. Thus a game that had presumably been developed for use by a single player on a single computer had been transformed into a paired collaborative activity as seen in many other educational settings (e.g. Inkpen et al., 1999) and further to a multi-player team effort with up to 10 children playing an ongoing game interwoven with doing other activities.

Additionally, and rather remarkably for this educational setting, the children mostly enforced the turn-taking themselves, as the first example below illustrates. The teacher was busy with the many other activities that were going on in free choice time. The children knew that they had somewhat modified the use protocols the teacher had created (by having more than two children engaged in the activity) and did not want to draw attention to that. Also, appeals to the teacher would use up their very limited time. This interesting situation of active rule enforcement by young children is explored in greater depth in (Wang, 2003). From the perspective of CSCL, note that in addition to any purported learning embodied in the application itself, the children were also independently learning important lessons about civics. These were not just about obeying the teacher’s rules, but also about how to interpret them and deal with special circumstances not covered explicitly by those rules, such as what to do if someone’s turn arrived but they had gone to the bathroom. Local policing and enforcement of the rules also had to be developed, for the reasons noted. There were frequent occasions where a child would be unwilling to relinquish their turn, or tried to cut in on the queue. The children resolved almost all these issues amongst themselves, by arguing from the rules, and by establishing alliances in exerting moral pressure (a child hogging the keyboard affected the access not just of the child whose turn it is, but the child who is next in line). It should be noted that in one sense this learning was not legitimate (see later). The teacher when asked was rather uncomfortable about its subversive nature: “I generally don’t want students to enforce the rules.”

Appropriation of Resources for Different Pedagogies

The following examples illustrate various kinds of help-giving learning or teaching techniques:

Sue: Where did you get the specifications from? Can you show them to me? Jared: [took over the mouse and keyboard and pulled out the information that Sue was asking for.] Sue: Hey, how did you do that?" I have never used that, what was it? Jared: Oh this is just a function from here, you go to the menu, type in the option and you get this results, it's a very straight feature. Sue: Cool, I will use it Part of a larger interaction where Jared had asked Sue for help in solving a design problem with a CAD system. In the process of trying to understand the details of Jared’s problem, Sue sees Jared obtaining the information she asked for in an unexpected way. She asks about it, and Jared repeats his actions more slowly so that Sue can follow them, describing them as well. Sue went back to her own workstation to look at some similar work that she was doing. She came up with a solution and walked back to Jared’s desk, took over the mouse control and keyboard control again and pulled the files that she wanted on his computer herself and then made some changes to the figure and then she told him "This is how it should be".	Cooperatively playing “Halo” a first-person “shooter” style game. They need to figure how to make their characters duck under a door. They have already tried many other approaches including looking for solutions that avoid having to duck under the door. Anne: [laughs] I’m thinking about tricks, you know? When I used to play Super Metroid… Sara: [experimenting with different buttons] This is ridiculous though. We aren’t even doing the point of the game. Anne: Yeah but we are trying to figure out how to duck here. OK Sara, I’m gonna pause the game. [Changes mind and doesn’t pause the game because Sara is still experimenting] OK, well you just keep doing it. I don’t think there’s a time limit. [Anne then picks up the game manual] [Reading out loud] A melee attack. Really. [Sarcastically] OK. Crouch. Left thumbstick button, press in. [Looks down at her controller] Oh! [puts down the manual] Sara: What? [looks down at her controller and puts thumb over left thumbstick] This thing? Anne: [Reaches over and presses down on Sara’s left controller thumbstick] Push this thing. [She continues to press the left thumbstick on Sara’s controller] Sara: Whoa. Yeah! [Both successfully duck under the stuck door and move to the next game section] Anne considers techniques from other applications that might help. They worry about time limits affecting their exploratory learning. Anne finally consults the manual, figures out what to do and shows Sara.
CSCW: Mutual learning and teaching	**CSCP: Using analogy and consulting the manual**

John: See where it says delete mail from server after so many days? Fiona: Mm hmm. John: I would recommend seven there. Fiona: All right. John: Just good practice." John is not only showing Fiona how to modify some initial settings of a mail program, but also suggesting some useful values	Carrie: You need an umbrella, a big umbrella! Ted: Yes! An umbrella. Celia: How do I get an umbrella? Carrie: Errr . . . Celia: Carrie, you find the umbrella pushing the mouse towards Carrie] Carrie: [manipulates the mouse and finds the umbrella] Now, you do it. [pushing the mouse back to Celia] Carrie is sitting and watching. She calls out strategic advice to Celia, who is operating the game. Celia doesn't know how to achieve the stated goal and asks. Carrie hesitates because she interprets the question as a request to take over and demonstrate. She is reluctant to go against the teacher's rules of who operates the computer and who observes. But when Celia more explicitly asks for her direct help she agrees, demonstrates the action, returning control to Celia, and challenging Celia to repeat the action herself.
CSCW: Showing how, what and why to act	**CSCL: Request, demonstration, practice**

[Kristen and Megan were playing, while Kevin and Nick were watching.] Kevin: Why don't you go the hockey place? [Timer goes off.] [Megan moves to the left chair & Kristen gets up and leaves.] Nick: [walking to the left to look at the waiting list] Who's next? Greg: [running to the list and writing down his own name] It is Ken. Nick: [turning around] Ken! Ken! Kevin: [turning back and pointing to the chair] Ken, come here. It is your turn. [Ken was busy with another activity] Greg: [grabbing the chair on the right, tries to sit down] Nick/Kevin: No, Ken is coming. Shortly after, Ken came to take his chair.	Tom: How did you do that? Ken: [turning around] What? Tom: Make the snow fall. Greg: You just press some . . . the fast button, see . . . [demonstrating on the keyboard.] Tom: The fast button? <overlapping speech> Jack: What is the fast button? Greg: [turning back] The "Esc" button! Underlined names are the children sitting at the computer 'officially' playing. Tom, watching the use of the application, is surprised by what he sees and asks for an explanation. He receives one, accompanied by a demonstration. The explanation uses a term he doesn't understand so he asks for a clarification and receives it. Jack is also watching and learning from observing the learning interaction between the others (an example of vicarious learning).
CSCL: Enforcing turn-taking	**CSCL: Opportunistic Learning**

We found many different learning approaches and pedagogies by which one person can learn how to use an application from another. These include: traditional instruction, demonstration with running commentary, apprenticeship, creation and use of microworlds, practice sessions, legitimate peripheral participation, use of external representations, competition, scaffolding, handicapping, grandstanding, vicarious learning, help suggestions called out in real time, story-telling away from actual use, and post action reflection and discussion. This list neither purports to be complete nor original. The aim is to illustrate the sheer variety of methods that can occur in informal learning and teaching. The following subsections examine some techniques in more detail.

Demonstrating with Running Commentaries

In all three cases people used commentaries on the action being undertaken. The nature of the commentaries varies somewhat, but they appear to be an important part of the wider interaction process.

In the workplace study, demonstrations were very important (Eales & Welsh, 1995). They usually involved a sequence of actions performed and described interspersed with higher level commentaries such as particular values to use that had been found useful for the work being done, and reasons why these operations and values were used for this kind of work in this work group. For example, an explanation of how to attach a document to an email also covered the choice of which mailing lists to send it to, how to find details of those lists on the intranet, and the important distinctions of who was on which lists that would help in deciding which lists to select, bearing in mind subtleties of work relations and office politics. See also the third example above. Furthermore, nearly all the problems and solutions observed involved the use of more than one application in their resolution (such as extracting information from a web-based database, incorporating it in a document and sending it as an email to someone else). The running commentaries helped the participants to keep track of the mental workflows and various workarounds that they tried. Since the solution did not reside in any single application, no application-specific interface design, manual, online help, or tutorial no matter how good would have helped. In such circumstances it was clear why asking a colleague for help was so valuable.

In the school situation, the two children playing would discuss the game while others would watch and offer suggestions, or offer to help or to show the pair how to solve a particular challenge. Since the game was being played in real time, there were occasions when advice was time-critical, so unlike the workplace commentaries, this led to shouts of advice to avoid a problem or seize an opportunity. Sometimes children could not seem to resist helping or offering advice, either through a burning desire to help, to show off their knowledge, or to see greater progress in the unfolding game and the group achievement of a final high score. Thus some of the help offered was unwanted, distracting, and even ignored or rejected by the intended recipients.

In the console game situation, time-criticality also mattered. Help could be solicited or offered, accepted or rejected, but it had to be done fast. Different kinds of commentary could also occur. Some was more analogous to sports broadcasting – an analysis for the benefit of a wider (imaginary) audience, but clearly also interesting to the participants. Another kind is "trash talking", when players would insult one another and/or their skills at the game. This was often accompanied with a harsher version of help giving. For example, one player might say "What an idiot – haven't you figured out that it's the 'a' button to shoot?"

Scaffolding

Many of the activities observed are different kinds of scaffolding (e.g., Quintana et al., 2002; Rogoff, 1990) that support the learning objective. Social scaffolding includes splitting up a task to make it easier to perform. This can range from simple division of labor to more conventional expert-novice work splits of strategy and tactics. Running commentaries can act as external memory, making the learner aware of issues that they need to act upon soon, and the consequences and meaning of the actions just taken. A partner may act as an emergency override, doing very little most of the time but ready to intervene if the user is about to do something dangerous, undesirable or difficult to recover from. The presence of such a social safety net can encourage more adventurous exploration than when investigating on one's own, where recovering from unintended consequences of explorations can be so confusing or onerous that it inhibits learning by exploring.

In the case of workplace help, the running commentaries create a structure for the learner to make sense of the actions being done. Rather than being an arbitrary sequence of semi-magic steps, the explanations give the steps meaning and help in chunking them together into groups that help structure the activity. For example, help in how to create a web page may involve use of more than one application, and needs to cover issues of making sense of creating the HTML, testing the local copy of web page with a browser, uploading it to the server using a file transfer program, and then re-testing the now public web page. Without clarifications of the steps and their meaning, a learner may become confused by very similar looking actions that have completely different meaning depending on where they are done in the larger action sequence.

In game design there is a technique called "rubberbanding" where an AI computer opponent might be "forced back" by the program if it is too far ahead of the human player, as if being snapped back by a rubber band. In multiplayer games, an example of social versus programmed scaffolding is where a more expert player might pause in a race to allow their competitor(s) to get closer, to make the game more challenging.

Peripheral participation: legitimate and illegitimate

Lave and Wenger (1991) introduce the concept of legitimate peripheral participation (LPP) as a way of understanding learning. We have found it a useful analytic framework in all three situations, as skills are shared and relative novices are helped to learn how to use the applications more effectively. However we also saw cases of contested legitimacy – learning activity that looks more like what might be called illegitimate peripheral participation. Note that Lave and Wenger take pains to emphasize that the components of LPP should not be considered in isolation, or in contrast to their antonyms. They would regard all learning as legitimate in the sense of meaningful for the learner. However we use the term 'illegitimate' to emphasize that some learning may be unsanctioned or subversive. For example in the classroom, the teacher believed that just passively watching others playing was a waste of time, and so had established a rule of "no watching". Children were meant to do another activity while they were waiting for their turn on the computer and move on to another activity after their timeslot ended. In practice, as noted, children lurked around the computer, but carefully trying to stand so that they were not perceived by others, particularly the teacher as too close. Occasionally one child would accuse another of 'watching', and this would be resolved in various ways, either by the watcher leaving, moving a little further way but still watching, putting their hands over their faces to imply that they weren't really watching (while peeking through their fingers), or most ingeniously of all, claiming to be 'observing', not 'watching'. Observing was an approved action in that classroom, associated with science activities. Bruckman (1997) notes an analogous episode in her study of the use of MOOs in education: "when a student at Massachusetts Public stood for a few minutes watching over one of her classmate's shoulders, she was admonished not to waste her computer time, and ushered over to an empty workstation."

INTERLEAVING WORK, LEARNING & PLAY

Our three contexts of play, school, and work just happen to match the sequence of three leading activities in modern industrial society - identified by Leont'ev (1981). These are typically viewed as distinct, but we were led to wonder about their actual or potential merging. In all three studies we saw cases of learning embedded in other activities. In the workplace, a problem causes a shift from doing the work to learning and problem-solving. In playing a game, players want to improve, which implies learning, and skill disparities may necessitate additional learning in order for all players to have an enjoyable time in a challenging competition. In interacting with peers and waiting one's turn to play a game in a classroom, children seem compelled to help each other improve. Work and learning clearly interleave, as do learning and play, and neither pairing is too surprising. But reflecting on each others studies leads us to wonder about the importance of play in learning in contexts outside the educational one. Although at first glance a rather strange idea, others have explored it including Gaver (2001): "There is a danger that as technology moves from the office into our homes, it will bring along with it workplace values such as efficiency and productivity at the expense of other possibilities. People do not just pursue tasks and solve problems, they also explore, wonder, love, worship, and waste time." We agree with Gaver's position, which explicitly draws on Huizinga (1953), that the design of technologies intended for non-work contexts needs to consider non-work human behaviors like play, and by implication also facilitate playful and at times collaborative learning of how to use home-based applications. However we would go further. The interleaving of the pairs of work & learning and play & learning led us to wonder about three-way interleaving. Do games have a component of work in them? Does the playing of games have implications for work? Do all contexts have some combination of work, learning, and play co-present in different ways and proportions?

Short but precise definitions of 'learning', 'work', and especially 'play' are notoriously difficult to create, as illustrated by Wittgenstein's (1953) exploration of the related problem of creating a precise definition of a 'game'. However we do think that there are attributes (or as Wittgenstein puts it, "family resemblances") of these kinds of activities that can or should be explored in different contexts. Learning is the least problematic of the three. It can take place in specially designated places (schools, universities, corporate training suites) or as a part of other activities (doing paid work, playing games, in the home, etc.). The idea of learning has attributes including reflecting, transforming, improving, practice, diagnosing, redesigning, and improving. The idea of work has attributes such as constructing, seriousness, effort, value, goal directedness, and worth. The idea of play has attributes such as joy, creativity, unreality, escape, wastefulness, lack of constraint, and exuberance. Even such a listing of attributes is controversial. However we have done so in order to begin to explore whether some of these attributes may appear in different ways and in different proportions in all contexts. This exploration of the attributes of learning, work and play helps show why people might feel uncomfortable with certain blending and why they sometimes try to keep play out of formal situations of learning, particularly in educational and training contexts, as well as out of work (Prensky, 2001).

Does workplace learning have a playful component in it, or if not, should it? Learning a feature in MS Word does not appear to be as much fun as figuring out how to get to Championship Level in Tennis 2K2. However, the informal workplace help-giving interactions observed often had some aspects of playfulness about them. Sometimes it was a break from routine work, or a chance to interact with a colleague as a change from solitary work. Sometimes social interactions (greeting people as they arrived or passed by) turned into a request for help. Nardi notes that even mundane work related applications such as spreadsheets led to the emergence of local developers who chose to spend more time 'tinkering' (a term implying playfulness); learning about the technology and interacting with programmers (Nardi, 1993). There is a growing body of research on issues of play or fun and its relation to computer use (e.g. Blythe et al., 2003; Pagulayan et al., 2003)]. Some of this work looks at informal use of computers either as games or as part of everyday non-work life. Others explicitly address the question of whether we can or should draw on computer games as inspiration for workplace tools, particularly to support the learning of those tools (e.g. Carroll, 1982; Draper, 1999; Malone, 1981; Neal, 1990).

Play is an important part of all human's behavior, serving a therapeutic role. The etymology of the word 'recreation' points to that. However we think that there is more to be said than encouraging workers to take periodic breaks maybe involving a short computer game. Rather we wonder whether some of the attributes we often ascribe to play are important in learning, and should be more explicitly validated and supported, equally in the workplace as in other environments such as domestic or leisure pursuits. Much is said about the importance of play in the learning of young children (e.g. Vygotsky, 1967), even noting how it can sere an emancipatory role in play forms that actively and expressly challenge the propriety of adult customs (Leont'ev, 1981; Duncan & Tarulli 2003), exactly as was found in the classroom study. Is there also a role for different kinds of playful activity in the learning of older children and adults? (Resnick, 1998; Landry, 2000; Prensky, 2001) We think that there are certain aspects of play that may be important in learning: apparent wastefulness, apparent unreality, and opportunities for creativity.

The Apparent Wastefulness of Play

Play is intrinsically motivating (Leont'ev, 1981). It usually involves doing something just for the fun of doing it, rather than to achieve a greater goal. It can be contrasted with work, which is usually done for its results, not just to be in the state of doing it. Play seems 'wasteful' compared to work. Similarly, learning often involves short term 'wastefulness', but in pursuit of a longer term performance gain. Even if the learning is tightly integrated with performance (as in apprenticeship and coaching), activities such as reflection, explanation, discussion, and practice of subtasks still entail a short-term performance loss. Learning seems to need some slack (interestingly, another meaning of the word 'play') in the system. With no slack, you just do the work; there is no time to consider how it might be done better in the future. We believe that an application can best support collaborative learnability (Eales & Welsh, 1995) by providing features that allow for the use of a range of different pedagogies.

These too will impose a performance overhead (both for the developers and the users of the application), and so are wasteful from the strict perspective of immediate operational efficiency. Nevertheless they are justifiable in terms of incremental productivity improvement via learning. This consideration of waste and learning has parallels with the work of Dewey, who had rather mixed views about play. For Dewey, waste in education occurs when the focus is on some hypothetical end far beyond the school (Dewey, 1907). It is then that we waste the precious resource of the child's experience. Conversely, work is actually wasteful when it removes the joy of life. He argues (Dewey, 1927) that the real productivity for society comes when work, too, promotes the full development of the individual, which requires both learning and play, embodying reflective action.

The Apparent Unreality of Play

Dix (2003) notes how young animal play can be regarded as a learning process, allowing the animal to practice its responses to potential life experiences such as hunting. Play allows learning through vicarious experience, but only if coupled with imagination so that the play experience in some way stands for something other than what it is – a kind of safe mental microworld. Unlike work, the activities taking place during play can be regarded in some sense as 'not real' in that they often do not have the same consequences as related activities in real life. Play isn't real, but it is like reality. Play might allow you to practice situations ready for encountering in real life, and try out new things in safety mode. Play is like many of the things we do in formalized workplace learning, including using models, scenarios simulations, scaffolding and practice (Schrage, 1999).

Opportunities for Creativity Through Play

There are two kinds of playful use; play *within* the application, exploring and learning its features and play *with* the application, using it in creative ways to achieve unexpected results. An aspect of the former can be found in Carroll's (1998) Minimal Manual approach to supporting workplace learning. This advocates encouraging and supporting exploration and innovation right from the start of learning a new application. It also has an emphasis on creating safe tasks and sequencing tasks safely, essential if playful behavior is to be encouraged. Dix (2003) notes the importance of play for engendering imaginative creativity that can be channeled into novel design ideas, particularly when childlike playfulness interacts with adult rationality. Such design ideas are likely to be very different from the incremental improvements of purely rationalist work-like analyses of a problem. It seems that certain actual and mental constraints are released in play enabling the asking of surprising questions about use. The importance of play for creativity has a long history (Schiller, 1955). Fischer has explored how creative insights are often initiated by breakdowns (Fischer, 2000; Schön, 1983) and has explored how to support both individual and social creativity. Similarly we found how breakdowns can lead to various different kinds of learning and teaching. We see playful interactions with many communications technologies leading to new styles of interaction, as for example with young people's use of text messaging, instant messaging and blogging (e.g. Grinter & Palen, 2002; Grinter & Eldridge, 2003). Some of these innovations are then adapted for other contexts, including work. Indeed teen socializing may not even be considered a form of 'play', but nevertheless the appropriation and development of the medium derived from playful interactions to discover new ways of using it.

INFORMING FUTURE WORK

Each of the three authors has been forced to re-examine their own studies and the implications they have for future research and design in the light of the findings of the other two studies. Here we consider some of the issues that arose from our conversations - although not immediately derived from the few particular examples that limited space forced us to select in this paper.

Designing for Appropriation of Use by More People than Intended

Thinking about designing to enable the collaborative learning of how to use an application should not just be a concern for the educational computing world. Rather, CSCL researchers have much to say to the developers of CSCW applications and even purportedly single-use applications about supporting collaborative learnability of application use. During breakdown a single-user application becomes briefly a CSCL application, raising the question of whether or how to explicitly support this brief ad hoc CSCL role. How should we introduce these ideas into design discussions where the concept of CSCL is alien? This is analogous to the struggles of many HCI researchers and practitioners to make the case that usability issues should pervade the software development process. It creates the need for lightweight techniques and guidelines as well as systematic development of exemplar functionalities and interfaces to explicitly afford temporary ad hoc multi-user interactions. Even within educational computing, a consideration of learning to use an application can be swamped by the far more prominent concern of using the application to learn something else. Inspired by the school and game cases we can explore the idea of extending a single user workplace interaction not just to a learning/helping dyad but to larger groups of people watching and participating. When would such kinds of public learning and group problem solving (say grandstanding round a cubicle) be appropriate? Are they ever efficient? How could software facilitate them? Is vicarious workplace learning useful and efficient, and how might it be supported? Does it suffer the same timewasting legitimacy issues as in the school, and are these concerns valid?

Designing for Spontaneous Appropriation of Resources for Different Pedagogies

There is no one right way to learn a particular application. Traditionally in CSCL we think of systems designers interacting with educators to select and create particular learning experiences using particular pedagogies explicitly designed into our software. However all three of our contexts reminded us that this is not the only way to do CSCL. It can be spontaneous and ad hoc, undertaken by the participants themselves, using or appropriating application features and interfaces to achieve the results they want using the pedagogies that they choose, without the benefit of higher degrees in education, psychology or computer science. The results may not be optimal, but there will be many situations when they are better than the available alternatives. It is provocative to us to consider how we might design to support these kinds of unplanned 'amateur' CSCL learning experiences and whether the need different support than the very carefully designed experiences more usually reported in the CSCL literature Different people will try different pedagogic techniques depending on the overall context and what seems to work. Indeed in one sense the application developer need do nothing. People appropriate application use to enable the learning of those applications by others, even when they are not themselves education researchers. But it is worth considering how we as designers might help that process (Dourish, 2003). We already have many checklists, heuristics and methods to inform design for usability and individual learnability (e.g. Nielsen, 1993). Can we work towards something similar for collaborative learnability? A low-effort starting point might be running through a list of pedagogic techniques and considering how to help people employ those techniques to support the learning of the application.

We believe that the issues identified have a number of implications for systems and interface design. In the case of games, features could be provided to support grandstanding and running commentaries, drawing on the kinds of actions done by TV sports reporters' use of action replays, selections of significant clips, annotations, use of statistics etc. More advanced features could involve completely separate interfaces (and most likely separate displays) for the players' and the commentators' creation of public displays and representations. Thus the players may focus in on the game interface while the commentator takes that feed and manipulates it as a TV sportscaster takes in and manipulates multiple camera feeds of a live sports broadcast. Asynchronous possibilities include the creation of edited highlights and compilations to show to others (including the original players), and to share these with others not present when the game was actually played. There are already examples of communities doing just this kind of activity. For example players of Quake create run-throughs of levels to illustrate their prowess (see www.planetquake.com/qdq/). Such run-throughs can also be used to illustrate gameplay or strategies to other members of their gaming community. Following our comparative theme we can ask when similar commentary and grandstanding activities might be appropriate in formal education and the workplace. Similarly the time-critical shouted out advice seen in games makes us wonder about learning about time-critical usage issues in the workplace.

Many games, especially sports games, have a single-player practice mode. However we are not aware of games that make it easy for two people to set up a training mode where a more expert player can show a novice player some critical skills without a game play penalty (i.e., showing the other player a skill that puts the game at risk for one or both players). An example of this might be a training room where players of a fighting game could spar against one another with no time restrictions or move that ends the game (unless of course the players choose to end the training themselves). Another example might be a skate park where players can teach one another basic boarding moves while not competing for trick points and/or racing each other. Formal handicapping is an effective way for players of different skills to compete in an enjoyable manner in games as disparate as go and golf, and so likely to be just as useful in computer games as an extension of the informal kinds we observed.

For workplace help-giving, we are investigating supplementary interfaces for supporting discussion of a help-giving interaction (Twidale & Ruhleder, 2004). Most help-seekers attempted a solution themselves before resorting to asking for help. However describing exactly what has been tried can be difficult, especially for non-expert computer users who lack specialist terminology. Mechanisms for recording and representing the process of a sequence of actions can support discussions of what has been tried so far, what might be tried next, and when a solution has been found, creating a record of what to do for future use (Favorin & Kuutti, 1996). Explorations of complex solutions occur when the help-giver is unsure of the solution, and wishes to experiment (or play) safely. This can be done by a skilled computer user, but greater support for experimental, exploratory, playful use, as compared with efficient use for regular tasks would help many users. The distinction parallels that between 'practice mode' and 'compete mode' in games. For CSCW applications in particular, practice modes may involve social scaffolding and may need the easy creation of multiple dummy logins for participants who are not taking on their official roles. It can help if some of those can be simulated, so that a practice session with 8-way communication can be achieved by just 2 or 3 participants.

In schools, a greater sensitivity to shared use is already impacting application design, such as options for splitting activity smoothly between keyboard and mouse, or between two sides of the keyboard (Inkpen et al., 1995). Other options might be to create scenarios for an extra person to take on a monitoring role to issue suggestions to the players actually directly interacting with the keyboard. Perhaps the most important implication is less for application design than for curriculum design. We wish to emphasize to teachers the different kinds of learning and social interaction that do already occur around such games (or other applications) in various situations, and to encourage consideration of wider lessons such as helping, turn-taking and the organization of group behavior. These are important skills for children to be learning and the organization of fair play around the game is worth considering as a 'teachable moment' rather than as an annoying, potentially disruptive and educationally lightweight play option.

The issue of legitimate or sanctioned learning that was discovered in the classroom forces us to consider whether it might play a role in other settings. Where else are certain kinds of learning contested? Are there cases where informal help is considered a threat to approved information sharing channels, a waste of time or inappropriate? Can unsolicited help be a problem? Similarly, the cutting and pasting of resources between several applications in the workplace in order to achieve a complex workflow task challenges the very idea of what counts as application design or end-user tailoring. How might we design to enable children or teens to playfully and creatively combine different programs to do a complex task or to invent a meta-game using a composition of several games or games with non-game software?

Designing for Interleaving Work, Learning and Play

How might we help encourage playful learning and creativity? The decision to play with an application, or to interact with it in a more playful manner than normal is to a large extent external to the application, being a matter for the individual(s) involved and their particular context. The application cannot and should not enforce playful use and maybe can't even successfully encourage it. The attempt can easily backfire, as the widespread negative reactions to Microsoft Word's 'Clippy' show. But can an application's design afford playful use, or at least not inhibit it? To support exploratory play, there needs to be relatively low effort cost, low consequences of failure or of undesirable effects, and clarity of actual or anticipated consequences. In other words it needs to be safe for the user(s) to ask questions like "I wonder what will happen if I do this?" and "Shall we try doing this for a short while just to see what happens?".

In work situations there may be a training infrastructure, but it is expensive and usually best suited to larger scale learning interactions (such as classes, seminars and courses lasting an hour or longer), or ticket-driven technical support for complex problems, rather than the lightweight ad hoc informal interactions lasting seconds that can particularly aid incremental learning. Thus there is still a need in the workplace to legitimate and encourage informal learning and help-giving. In many non-work situations, there will be no extensive training infrastructure. For example, applications for domestic use are more likely to need to rely on both individual learning and informal help-giving between family members and friends. Explicit support for this could be crucial to adoption in enabling users to overcome the learning barriers to powerful but complex functionalities.

Other Contexts for Learning

Fortunately in some contexts, the very act of learning and help giving can become part of the point of the interaction rather than a desirable but nevertheless overhead on the main activity of using the application. For example, many researchers are investigating the use of collaborative applications to support the sharing of digital photographs (e.g. Frohlich et al., 2002). As those researchers note, this is not just about the access and transferring of files that happen to be images. Rather it is about providing technologies that families can use and indeed appropriate to share experiences, and memories, to precipitate story-telling, and so to interact with each other. Given such a situation, a scenario of a grandchild showing a grandparent how to use the application to create a special album or display is not an example of a learning overhead, but part of the very point of the application. Consequently the design to support such kinds of help-giving deserves just as much attention as the design to support the purported use of the application.

CONCLUSION

From three separate studies in three very different use contexts we have come to a deeper realization of the ways in which people use an application to support the learning of that application by others – creating spontaneous or ad hoc CSCL. This led to an exploration of how to design to support the varied pedagogies that may be used in such collaborative learning of applications. The role that play and playful behaviors can play in the learning of applications and in the development of creative solutions was also explored, leading to a consideration of how to design to support playful use.

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Exploring Collaborative Aspects of Knowledge Building Through Collaborative Summary Notes

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Abstract. We explore the use of collaborative summary notes in Knowledge Forum™ (KF) as a way to capture the distributed nature of knowledge advances among groups of students building knowledge together. The purpose of this exploration is to develop assessments that can be used for *scaffolding* the discourse and promoting ideas within the community, as well as for evaluation. The unit of analysis was the group on KF. Students in two high school classes collaborated on a progressive inquiry exploring aspects of a recent SARS outbreak and some related topics. They were asked to write collaborative, co-authored, summary notes to make the nature and importance of the knowledge advances they achieved clear for their peers. The findings indicate that note ratings were positively related to the number of co-authors and the number of views (different discussion spaces) in which students had worked.

Keywords: Knowledge building, assessment

INTRODUCTION

Theories informing CSCL (Computer Supported Collaborative Learning) posit learning as collaborative and distributive (Brown, Collins, & Duguid, 1989; Salomon, 1993; Stahl, 2002), and more emphasis is now placed on learning as participation in the practices of a culture (Roth & Tobin, 2002). Assessment practices have not kept pace with these developments (Shepard, 2001). Chan and van Aalst (2004) identified three problems with teacher-administered assessments. First, assessments need to capture both individual and collective aspects of learning. Second, there is a need for assessments to capture both the learning outcomes and the (collaborative) learning process. Third, there is a need for greater alignment of learning, assessment, and instruction. Currently, it is widely recognized that assessment is part of the instructional process and it plays a central role in *scaffolding* (i.e., guiding) student learning (Shepard, 2001). With the changing conceptions of learning emphasizing social and constructive nature of learning, there is a need to develop social-constructivist assessments that give students the responsibility to assess their collaborative processes and learning outcomes.

An example of an educational approach using a CSCL technology is ‘knowledge building’, defined as “the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts” (Scardamalia & Bereiter, 2003, p. 1370). Knowledge building emphasizes that knowledge is the achievement of a community, and is improvable by means of discourse (Scardamalia, 2002). Although much of a knowledge building discourse takes place in face to face interactions, a CSCL environment is often used to support it and to provide a reliable trace of how ideas are developing. Students can use this trace to reflect on the community’s learning. The software most often used by proponents of Bereiter and Scardamalia’s version of knowledge building is Knowledge Forum™ (KF), which has some specific features designed to support *working with* knowledge. Some of these features are different ways to link notes (e.g., adding them as references to a new note), and *views*. A view refers to a space where notes are located, similar to a “conference” in other CSCL environments. Students can create new views when, for example, a need for a new discussion is emerging and they need a space for that discussion.

van Aalst, Chan, and Lee developed a portfolio-based approach to assess the *process* of knowledge building (Chan & van Aalst, 2003, 2004; Lee, Chan, & van Aalst, this volume). They introduced a small set of “pedagogical knowledge building principles” describing collective and individual aspects of knowledge building: (a) working at the cutting edge, (b) progressive problem solving, (c) collaborative effort, and (d) identifying high points of the discourse. For example, their principle ‘working at the cutting edge’ requires that students collectively raise significant problems, that is, problems that take the range of ideas within the community as well as the available authoritative sources of knowledge into account; it further requires that the community investigates at least some problems of this kind. Chan and van Aalst (2003) asked students to develop electronic portfolios in KF, using clusters of notes in the KF database as artifacts. This approach revealed some metacognitive benefits, as students realized that the need of developing these portfolios helped them understand how they could best align their work in KF with knowledge building theory. Whereas these studies examined distributed phenomena, the unit of analysis in the assessment was the *individual learner*. More research is needed to improve the coherence of the assessment task and the phenomenon that is being assessed: collective phenomena should also be assessed at a collective unit of analysis (Stahl, 2002).

A pedagogical problem highlighted by literature on knowledge building is that the completion of tasks takes center stage in school (Bereiter & Scardamalia, 1993; Hewitt, 2002). This does not mean that tasks are unimportant (see Collins, 2002, for a discussion), but that the tasks are more prominent in the students' thinking about what they are doing than the learning goals. Students are more likely to say that they are writing an essay than that they are trying to articulate lessons learned from their analysis of a problem, so that those lessons learned can find their way into the community's knowledge base. Although Hewitt analyzed the problem in terms of instructional design and teacher roles, assessments also contribute to the problem because assessment and instruction are "two sides of the same coin" (National Research Council, 1996; Shepard, 2001).

The goal of this study was to explore an assessment strategy designed to capture collective as well as individual aspects of knowledge building. Most of the analysis focuses on a collective unit of analysis—a group on KF. The students were asked to write collaborative summary notes to make the nature and importance of what they learned clear for their peers. These notes were coauthored by all students in a group who were judged by the students to have made significant contributions to that learning. The task required that students reflected on the distributive nature of knowledge.

METHOD

Participants

The participants were students in a grade ten course on career preparation and research techniques (n = 21) that was part of a pre-IB (International Baccalaureate) program, and a grade eleven course on computers and their impact on a "global society" (n = 19), both taught by the same teacher at an inner city school in a metropolitan center in Western Canada. Some of the students (approximately 40%) were familiar with KF. However, the students did not have prior experience conducting an extended collaborative inquiry.

The teacher

The teacher (the second author) had ten years of experience teaching mathematics and computer studies in middle and high school. He completed a masters degree focusing on cognitive strategy instruction in 2002 and was in his third year of teaching with KF. Prior to starting with KF in 2001, he attended a four-day workshop on knowledge building led by Scardamalia and colleagues. The teacher gradually attempted to integrate knowledge building more fully into his teaching. In the first year he taught grade eight mathematics and posted weekly "challenge problems." His belief that students needed considerable skill development (factoring, solving equations, etc.) to prepare for the next grade was an obstacle in attempting a more discourse oriented approach to mathematics teaching (e.g., Lampert, Rittenhouse, & Crumbough, 1996). The next year, he taught a grade nine course on personal development and research techniques that offered more flexibility. However, in this course he also felt that students first needed to develop research skills before attempting knowledge building and he had relatively little time available for knowledge building. The teacher's approaches up to this point reflect an often held expectation that students need to develop foundational skills *before* they can successfully engage in knowledge building, rather than developing those skills in the context of student-directed inquiry. In the year of this study, the teacher was ready for a more extensive implementation of knowledge building and agreed to a two-month student project starting within a few weeks of starting the course (i.e., without taking time for foundational skill development).

Procedures

At the beginning of the school year the teacher and researcher met several times to discuss how to make the pedagogical knowledge building principles (Chan & van Aalst, 2003) more central to the class's work, as well as the role and nature of the final products the students should produce. A two-month unit was then designed in which students could investigate some problems then of interest to Canadians—SARS, Avian Flu, and computer viruses. These topics were current, and had a loose connection to the curriculum: research for the grade ten class, and the use of a CSCL environment for the grade eleven class. The two classes shared a KF database and worked on the same topics; the students were divided into four groups with an equal number of students from each grade in each group. Each group had its own virtual workspace in KF and was not required to interact with the other groups. Both classes had daily access to a computer lab during class time. A three-phase inquiry model was used to provide some structure to students by which they could manage their inquiry (van Aalst, 1999). This was considered necessary because both the teacher and students had limited experience with extended collaborative student projects. The three phases of the project are described below.

Phase one(two weeks): The students read widely in this general area, using internet resources as well as paper resources. The goal here was to enable students to identify some problems that they could investigate (Polman, 2000). The students were then encouraged to prioritize a few of these problems and to develop brief proposals. The goal of this process was to ensure that each group had promising ideas for inquiry, as well as adequate resources. The end of phase one resulted in collaboratively written proposals (in KF). To do prepare these proposals, students first developed a process for prioritizing the problems that had emerged, as the students in each group came form both classes and did not all meet face to face.

Phase two (four weeks): The students researched their problems collaboratively, reading information on the internet and from other sources. The students were encouraged to evaluate the likely credibility of the sources (i.e., a web site by the World Health Organization could be more trustworthy than one by a person not declaring his/her credentials), and to examine the evidence for the claims made in the sources. Some papers from professional journals were introduced by the researcher to improve the collection of trustworthy sources students were using.

Phase three (two weeks): Collaborative Summary Notes were introduced as a way to articulate what the group had learned about each problem it had investigated and on which it felt it had made some progress. These notes followed a scientific genre in which students (a) stated the problem on which they were reporting; (b) explained the background of the problem, linking to their work in phase 1 in which they identified problems; (c) described what they did to investigate the problem and reported the main findings; and (d) explained the significance of the findings as well as their limitations. The instructions to students, provided by the researcher, stated: "Each note should report what the class has learned about a specific question. Do not write notes about questions that you think you did not learn much about. … Overall, there may need to be perhaps 20 to 30 notes, but it may also be considerably less." These instructions also pointed out that a specific student could be a co-author of several collaborative summary notes.

Data sources, measures, and analyses

The following data were collected:

Server log data: To provide a general description of the KF database, the Analytic Toolkit for KF (Burtis, 1998) was used to examine the following variables: number of notes written, number of notes that were linked to other notes, number of views worked in, and percentage of notes in the database that a student had read. According to Burtis, these data are basic indicators of knowledge building. Students are expected to make connections between ideas, which is typically represented by a high percentage of notes that are linked to other notes.

Ratings of collaborative Summary Notes: The collaborative summary notes were evaluated with the rubric shown in Table 1. This rubric was provided to the students by the researcher and follows a style similar to other rubrics used by the students at this school. All the summary notes were scored independently by the researcher and a research assistant specializing in educational technology, leading to an inter-rater agreement of 82%.

Table 1
Rubric for Assessing Collaborative Summary Notes

Criterion	D	C	B	A
Structure	At least two components of the note are superficial or missing (1)	At least one component of the note is superficial or missing (2)	All parts are complete, but the note may be longer than necessary and lacks focus (3)	All parts are complete and reasonably succinct (4)
Co-authors	Not done (1)	Significant omissions in the author list, or it is just a list of friends (2)	Most students who contributed to the ideas and work are co-authors; there may be some students who made only minimal contributions. (3)	All students who contributed to the ideas and work are co-authors, but no students who made only minimal contributions are coauthors (4)
Findings; significance	Significant errors in the reported findings; importance of findings is not pointed out (2)	Some reported findings are incorrect; the reported importance of the findings is questionable (4)	Findings are factual; the importance is explained clearly, but some limitations are not pointed out (6)	Findings are factual; the importance and limitations are clearly explained (8)

RESULTS

ATK indices

The two classes collectively wrote 491 notes (not including the collaborative summary notes). To examine if there were differences in participation levels in KF, as measured by the ATK indices, a Group on KF by Grade MANOVA of the three ATK indices was performed. The findings indicated that there were no statistically significant main effects. However, there was a significant Group by Grade interaction for Notes Written, $F(3, 32) = 5.19$, $p = .005$, $\eta^2 = .33$. Further analysis revealed that this was because in group B, grade eleven students wrote considerably more notes than grade ten students (on average16, compared with 6). Table 2 shows means and standard deviations for notes created, the percentage of notes that were linked, and the percentage of notes read for the four groups on KF.

Table 2
Mean (SD) ATK Statistics for Four Groups on KF

	Group A	Group B	Group C	Group D
Notes Created	14.9 (4.7)	11.2 (6.4)	15.9 (5.3)	13.1 (3.3)
% Notes Linked	47.1 (18.0)	40.9 (18.5)	50.4 (15.3)	45.3 (17.3)
% Notes in database Read	30.5 (13.7)	31.7 (20.3)	18.6 (4.7)	20.0 (5.2)

These findings indicate that participation levels were somewhat higher than reported in other studies. For example, Hsi (1997) found that grade eight students wrote on average 4.82 notes over an 18-week period. However, the percentage of notes linked was lower than expected. In some other classrooms, this measure was in excess of 80%.

Initiating the inquiry

In phase one, the students did background reading and formulated research questions. Collectively, the students contributed 200 notes during this phase (40.7% of the database), reflecting that students spent considerable effort to articulate, refine and prioritize problems. Of the 200 notes, 55 notes (27.5%) were single notes, 89 notes (44.5%) were in 31 threads of 2-5 notes, and 56 notes (15.5%) were in 7 threads of 6-10 notes. These thread lengths are commonly observed in online discussions (Hewitt, 2003). Within each group, between 42 and 50% of the notes were read.

The different groups each used approximately one-third of the notes in phase one to organize the task. (Not all students had face to face contact, as they were from two classes.) For example, "… We're a little concerned that not everyone will be gaining equal knowledge on these topics because some of us will not be as articulate or as good in research as the others. Also, we will be true 'experts' on only the subjects we researched on. It's important that everyone has a good idea about all of the subjects to be covered." (a group D student). Other notes reported information that students found, and further questions that emerged.

At the end of phase one, the students formulated research questions and voted on these to come up with a small number of questions that they could research further in phase two. For this the researcher provided sample notes which included the question, background, proposed procedures, and expected outcomes. Group D chose to focus on the following questions. 1) How does fear affect our outlook on viruses? 2) What is the most effective way to minimize the spread of Avian Flu? 3) What caused the recent outbreak in China? How did it return? Other groups focused on the economic impact of SARS and on avian flu. For example, group A asked "Why does the Avian Flu only transfer by being in close proximity to poultry and not through eggs or meat?" Group B asked "Why has the media blown the SARS incident into such a large media explosion? If they hadn't have, would it have become a larger problem?" The discourse leading up to the research questions merits deeper analysis than we can provide here, but from these examples it appears that all groups arrived at explanation-seeking questions (e.g., Lipponen & Hakkarainen, 1997).

Collaborative Summary Notes

The students submitted 32 collaborative summary notes describing their knowledge advances. The notes were evaluated using the rubric shown in Table 1; the rubric assessed the structure of the notes (4 points), the extent to which students correctly gave credit to the contributions of collaboration (4 points), and the reporting of the findings (8 points). The total of these scores was divided by four to obtain a note score between 0 and 4. We first present one sample summary note and analyze its features in terms of the rubric, and then report the note ratings for all summary notes. Ten of the 32 summary notes can be viewed on the internet in a virtual tour (www.educ.sfu.ca/kb/KF_Databases/KF_Databases.htm, last visited February 28, 2005).

Sample summary note

The note shown in Figure 1 was written by a grade 10 student, and was co-authored by two other grade 10 students and three grade 11 students.

> ***Research Question*** What is the economic impact of small-scale or large-scale quarantine? How much are we willing to damage the economies of affecting countries to ensure that Avian flu doesn't spread? How much is it costing the government to have birds tested, in relation to how much it's costing poultry farmers to slaughter their chickens?
>
> ***Background*** Looking at the SARS outbreak that occurred last year, many countries and their economies were affected. The tourism industry for many cities like Toronto experienced a major decrease in the number of tourists that were visiting. Everyone was scared and worried about getting infected. Now that the Avian Flu is spreading, again the fear of getting infected, or having your chicken get infected is everywhere. There have been outbreaks here in BC, close to home, so it is important and interesting to look at how this virus has impacted our economy, and how worse things might get.
>
> ***Method*** To find information, I read information from different websites. I mainly looked for news articles, or sites that belonged to the WHO or other organizations, because I think that these are reliable sources, and have good information about the Avian Flu and its consequences. I also read the notes posted by everyone in our group, and posted my own notes to share the information I found.
>
> ***Findings*** I found that the main country that has been affected by this virus is Thailand. It has seen a 13% drop in the number of international arrivals. Also, during the first three months of this year, the export value of poultry products in Thailand had a significant decrease (94%, and frozen products dropped 68%).
> Besides Thailand, Vietnam has also been affected and is expected to have a cost of $690 million for the culling of poultry. An outbreak in Hong Kong will cost over $10 million (US), and the outbreak here in the Fraser Valley could cost about $3 million a week. This shows that the Avian Flu is causing damage to the world's economy, even though it might not be as bad as SARS. It wasn't expected that Avian Flu would have such a great impact, and some experts are saying that the costs aren't too bad in some areas, when compared to SARS.
>
> ***Importance of Findings*** So, by looking at the economic impact of Avian Flu, we can see how something small, and maybe not very important can become a very big problem. This virus began in birds, but has spread to humans as well. This spread is creating fear among everyone. Also, starting in Asia, this virus has spread over the globe. So many chickens are being killed, farmers are losing their businesses, and this is creating a huge loss of money. Earlier it was expected that the Avian Flu wouldn't have such a great impact, and would be lower than SARS. Maybe the amount isn't as great as it was for SARS, but it shows how something small can spread and get bigger, and could lead to a great loss.

Figure 1
Sample Collaborative Summary Note

This note received an overall rating of 2.5 out of 4.0, and was ranked 19 out of 32 (1 being the highest score). All of the sections were present, but some sections could have been done better. example, the background section could have provided links to specific notes the group had written as part of the work it had done to develop the research questions. The note received 3 out of 4 for structure.

With regard to authorship, the note was co-authored by six students, which may be taken as a self-report of how the main author thought the learning was distributed over group members. In some places, the main author wrote in the first person ("To find information, I read information from different websites") suggesting that we are dealing with the main author's personal learning. There also could have been evidence for specific contributions made by co-authors, for example, by linking to notes written by them. Therefore, the note received 2 out of 4 for crediting co-authors. Many of the other summary notes were written in first person and lacked specific credit to co-authors, as was the case for this note. This suggests that although the notes may have reflected what the group had come to understand as a result of collaboration, the students needed more guidance and time to make the notes reflect that. It is likely that many of the notes were written on behalf of the author group by a single author.

The note reported some findings and explained what they contributed to the class's understanding of Avian Flu. However, the note does not accurately reflect what the group discussed and, by the teacher's observation, understood. Certainly, after nearly a month of research on these questions (after phase one) by six students we would expect to see more evidence for understanding. The note received 5 out of 8 for reporting findings and implications. The ability to capture what the group had learned was a problem with many of the notes.

Overall, we were very pleased with most of the notes, including this one. However, our analysis indicates that work could be done with the class to improve its understanding of and proficiency at some of the processes involved in creating a summary note. Coming late in the course, the students were rushed in completing the assignment. In future, students could write summary notes throughout various inquiry projects, and thereby have opportunities to improve them over time.

Quantitative analysis

Table 3 shows the scores for the different sections of the collaborative summary notes, as well as the overall scores.

Table 3
Evaluation of 32 Collaborative Summary Notes

	Min.	Max.	Mean	Std. Dev.
Note Structure	1	4	3.06	1.19
Co-authors Named	1	4	2.09	1.09
Findings and Implications	4	7	5.13	0.83
Note Score	1.50	3.50	2.57	0.61

Attention to the note structure was generally as expected (research question, background, method, findings, and importance of findings), although in some cases one or two sections were underdeveloped. For the properly naming of co-authors the mean score was 2.09 out of 4. Some notes listed students as co-authors but did not make clear what the contributions of the co-authors were. For example, the students could have cited notes by co-authors more often in the summary notes, or they could have described their contributions in words. The *Findings* and *Importance of Findings* sections were generally somewhat underdeveloped (mean score 5.13 out of 8). Some notes described the findings in general terms without going into the specifics of what the group had learned.

The 32 notes were divided into two levels with note scores below and above the median score. As Table 4 shows, group B wrote a relatively high number of notes with scores below the median (7 of its 9 notes) whereas group C wrote relatively few summary notes (5, compared with 9 for the other groups). Group A had the highest proportion of notes above the median. Although there were some between-group differences, no corresponding differences were found for grade level.

Table 4
Classification of Collaborative Summary Notes

		Group A	Group B	Group C	Group D	Total
Note rating	above median	6	2	3	4	15
	below median	3	7	2	5	17
Total		9	9	5	9	32

The notes were also examined for the impact of the number of co-authors (not the rating the notes received for this) on the overall note ratings. As Figure 2 shows, notes receiving scores below the mean tended to have fewer co-authors than notes with overall ratings above the median; a Mann-Whitney test showed this effect was statistically significant (Z = -2.97, p = .007).

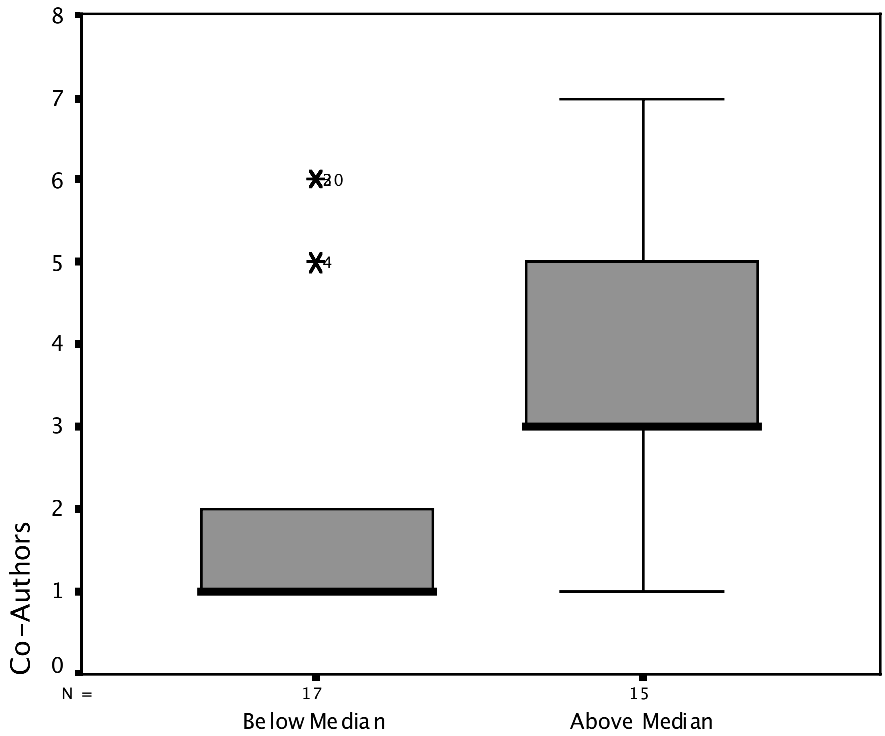

Figure 2
Number of co-authors with Note ratings below and above median

Exploring the collaborative summary notes as assessments

Summary Note scores

There are many ways to obtain measures of collective (i.e., group) and individual achievement, and we explore the following two:

Group Score: The sum of the scores for the summary notes by the group divided by the umber of students in the group.

Individual Score: The highest of the overall ratings of notes that the a student co-authored.

Table 5 shows the group scores, as well as the group averages and standard deviations of the individual scores. As one may expect, not every student co-authored at least one note: 17 grade ten students (81.0%) and 16 grade eleven students (84.2%) were co-authors of at least one summary note. In this study, the summary notes were not used for formal student evaluation; if they had been, the teacher would have worked with the students more to ensure that their contributions to KF would be counted towards their grade. Therefore, we report statistics only for students who co-authored at least one collaborative summary note.

Table 5
Group Score and Mean (SD) of Individual Score

	Group A	Group B	Group C	Group D
Students in Group	11	10	10	9
Co-authors in Group	10	8	7	8
Group Score	2.27	1.88	1.45	2.67
Mean Individual Score	3.20	2.34	3.14	3.19
SD of Individual Score	.39	.48	.38	.53

As Table 5 shows there were considerable variations in the group scores. The group scores are influenced by three factors. (1) The proportion of the students in the group who actually were co-authors of at least one note. This ranged from .70 for group C to .91 for group A, and is a measure of the extent to which learning is a distributive property of the group. If it is low, it suggests that some students were not represented by the summary notes. (2) The productivity of the group, the number of summary notes divided by the number of co-authors. Some groups may have learned more than other groups or took the assignment more seriously. In this study, this measure ranged from .72 (group C) to 1.125 (groups B and D). (3) The quality of the summary notes, as described by the rubric. These measures combine to form the group score as shown by the following formula:

$$GS = \sum_i \frac{n}{N} \times \frac{f_i}{n} \times NS_i$$

Here GS is the group score, n the number of co-authors, N the number of students in the group, f_i the frequency of note score NS_i, and the summation is over the different note scores for a group.

Regarding the *individual scores*, one may expect grade eleven students to outperform grade ten students because they are academically more advanced. However, a dependent samples t-test showed this was not the case, $t(31) = .545$, $p = .59$, two-tailed. A one-way ANOVA revealed a significant Group on KF effect, $F(3, 29) = 7.096$, $p = .001$, $\eta^2 = .42$; a post-hoc test (Tukey-Kramer) showed that the mean for group B was lower than the means for all the other groups, with no differences among groups A, C, and D.

Relationship between individual scores and ATK indices

Among the 32 students who co-authored at least one summary note, the individual scores were correlated with the number of views on which a student had worked, $r = .42$, $p = .017$. Regression analysis of the ATK data showed that Notes Created was the strongest predictor of Views Worked On, adjusted $R^2 = .24.$, $p = .01$. (This is usually considered a moderate association, see Abrami, Cholmsky, & Gordon, 2001.) Although previous research has revealed a relationship between Notes Created and measures of understanding (van Aalst, 1999), in this study there was no direct relationship between Notes Written and the individual note scores. What mattered more than writing notes was to create and work on multiple views. The creation of views is to some extent an *emergent property* of the discourse—students create views as needed by their inquiry; Bereiter (2002) has argued that emergence is an important feature of knowledge building (also see Sha and van Aalst, this volume). So, potentially the individual summary note scores capture an important aspect of knowledge building.

DISCUSSION AND IMPLICATIONS

In a well-functioning scholarly community, people are rarely begin a research project to produce a paper. Instead, they work on problems that interest them and that can advance the state of knowledge in a discipline (Bereiter & Scardamalia, 1993). When they feel they are making progress, they engage in a variety of tasks—including writing papers—to make that learning available to the discipline for debate, further testing, and application. In a scholarly community, *understanding* a problem is not enough. The understanding achieved must make impact on the state of knowledge in that field, and that means that people must work to promote their ideas. Yet, when we look at many implementations of CSCL technologies—KF included—the purpose of online discussion and "research" is to learn enough to write a paper that does not serve such a function. That is one reason why proponents of knowledge building often speak of the task-oriented nature of schooling (Hewitt, 2002; Bereiter & Scardamalia, 1993).

In this study we explored an assessment task that may help us do better. The premise of the task was that learning, is distributed, and that at least some assessment tasks should capture the distributed nature of achievement. The students were asked to prioritize problems on which they would work collaboratively and then wrote collaborative summary notes; they were asked to acknowledge the contributions of all students who contributed to the group's current understanding. In this study, the assessment task came at the end of the course, was designed by the researcher rather than the teacher, and was not part of the formal evaluation scheme. No doubt, the students saw it as "just another assignment." In future, the task needs to be designed by the class, and it needs to be embedded in knowledge building discourse (Scardamalia, 2002), so that the summary notes can be used to promote ideas. In this regard, the use of an inquiry model in which different inquiries had the same temporal scale (van Aalst, 1999) was constraining. In a real knowledge building community (e.g., a scientific community), new inquiries are beginning all the time, and different groups report their findings whenever they are ready to be reported. Thus, we need to think about a knowledge building community in a more fluid way than the inquiry model allowed. Then students write collaborative summary notes throughout the life of the community (once the community has had a chance to develop to some extent), and there are opportunities for gradual improvement of the practice of writing collaborative summary notes.

Our analysis of the summary notes identified several promising effects. First, more than 80% of the students made contributions to at least one summary note. That is an indicator of what Scardamalia (2002) calls the "democratization of knowledge," and it can be used to reflect on and improve the class discourse. Second, summary notes with more co-authors received higher ratings. This effect marks a possible benefit of collaboration, presumably through the diversity of the ideas and perspectives accounted for in the summary notes. However, for many notes this finding was based on *self-reports* and not on evidence identifying specific contributions to understanding by individual students. Third, the weakest aspects of the notes in terms of the ratings were summarization and making the importance of findings clear. This is not surprising as the students had little experience with the task, but it does suggest that cognitive strategy teaching (the teaching of framing questions, summarization, etc.) is necessary to improve this aspects of the notes. Nevertheless, we suggest that it is not necessary to deal with this issue *before* knowledge building, as had been the teacher's practice in the past. *Indeed, we propose that cognitive strategy instruction should be situated in the class's efforts to improve* *on the knowledge building discourse, as revealed by assessments of this kind.* Previously, we argued for a similar scaffolding function of assessment in the context of portfolios based on pedagogical knowledge building principles (Chan & van Aalst, 2003).

Most of our analyses used the group on KF as the unit of analysis, and some analyses revealed significant differences among these groups. Data from this assessment can therefore be used to interpret how the group is doing as a community. In this study, group membership remained fixed throughout the class's work, but that is not necessary. Groups can be assembled as needed by specific lines of inquiry that emerge in the class's work, and a group that works together for a short time can contribute one or more summary notes to the community discourse.

Students are individuals, and we cannot completely escape evaluating individual students. In this study, we went for simplicity and used the *best score* from all the summary notes a student co-authored to create an individual score. This is clearly a subjective choice, and other researchers and teachers may prefer to use central tendency measures such as the mean or median. The measure we used had a medium correlation with the number of views a student worked on. Although the number of notes created was a predictor of views worked in, it was not correlated with the individual scores. This finding is different from previous findings indicated that the number of notes created is a strong predictor of conceptual understanding (van Aalst, 1999). The current finding may reflect *emergent properties* of knowledge building, viz. that a group creates new views to accommodate the needs of the discourse.

We see the assessment task we have discussed as *prototypical*. Additional assessment tasks are needed that explore different ways of obtaining individual scores that can be used to scaffold and evaluate knowledge building. Additional research is also needed to examine relationships among the summary note scores and other assessments such as growth of domain knowledge and a range of trait variables. It also requires research to establish the findings reported above in settings where the assessment task is used for formal evaluation.

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Towards a Dialogic Understanding of the Relationship between CSCL and Teaching Thinking Skills

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Abstract. This paper reviews the literature linking information and communications technology (ICT) to teaching thinking skills and advocates a dialogic framework which has implications for practice. The computer supported collaborative learning (CSCL) movement is critiqued for not always taking into account the radical implications of the concept of 'dialogic' which is the idea that meaning-making requires the inter-animation of more than one perspective. It is argued that dialogue and dialogic is the key to 'learning to learn' and other higher order thinking skills and that the unique features of ICT particularly suit it to inducting learners into learning dialogues and to the deepening and broadening of dialogues as an end in itself.
Keywords: Affordances; CSCL; Creativity; Dialogic; Learning to learn; Thinking skills.

INTRODUCTION

From its inception the use of computers in education has been linked to the teaching of thinking skills. However the relationship between computers and teaching thinking has been conceptualised in a range of different ways. Initially computers were seen as teaching machines programmed to directly instruct students in content and skills. Papert and others responded to this with a constructivist learning theory and software that could serve as tools and environments for actively learning thinking skills. Both these movements tended to focus on individual learners. In the last two decades there has been a development of research on computer supported collaborative learning (CSCL) drawing on various theoretical sources including socio-cultural theory and situated learning theory. In the CSCL movement there is considerable interest in teaching group thinking skills in the form of computer mediated collaborative problem-solving and argumentation. This paper argues that a truly 'dialogic' perspective could clarify the relationship between information and communications technology (ICT) and teaching thinking in a way that can guide practice within the field of CSCL. This dialogic view shares with socio-cultural theory the idea that individual thinking skills originate in mediated dialogues, however it goes further in claiming that it is not the appropriation of tools but induction into dialogue which is the primary thinking skill, reconceptualised as 'learning to learn', with all other thinking skills following from this induction. This perspective suggests that the main role of technology in teaching thinking skills should be to open and maintain dialogic spaces in which different perspectives co-exist and inter-animate each other.

In order to develop this argument the paper begins with a brief account of thinking skills and a recapitulation of some of the main positions relating thinking skills to ICT.

THINKING SKILLS AND ICT

'Thinking skills' and related terms such as 'learning to learn', are used to indicate a desire to teach processes of thinking and learning that can be applied in a wide range of real-life contexts. The list of thinking skills in the English National Curriculum is similar to many such lists in including information-processing, reasoning, enquiry, creative thinking and evaluation. While some approaches to teaching thinking treat such skills as separate, other approaches treat them all as aspects of high quality thinking or 'higher order thinking'. Higher order thinking is said to be complex thinking that requires effort and produces valued outcomes (Resnick, 1987). In practice thinking skills programmes do not all focus on the narrowly cognitive but promote a variety of apparently quite different kinds of things including, strategies, habits, attitudes, emotions, motivations, aspects of character or self-identity and also engagement in dialogue and in a community of enquiry. These 'thinking skills' are not united by any single psychological theory. The only unity they have is that they are all those sorts of things that practitioners believe can and should be taught or encouraged in order to improve the perceived quality and/or the effectiveness of their students' thinking. (Wegerif, 2003)

Surveys of the use of computers to promote thinking skills (e.g. Hughes, 1990; Underwood and Underwood, 1990) draw a sharp distinction between the use of computers as a tutor to teach thinking skills and the use of computers as a tool in order to develop skills indirectly. According to Solomon (1987) these conceptualisations, computer as tutor and computer as tool (from Taylor, 1980) are reflections of two traditions in educational psychology: the Behaviourist/Empiricist tradition that conceptualises learning as acquiring and applying associations and the Cognitivist/Rationalist tradition that conceptualises learning as acquiring and using conceptual and cognitive structures. In the handbook of educational psychology Greeno, Collins and Resnick (Greeno, et al 1996) re-iterate this distinction and also outline a third, more recent, strand which they refer to as the Situative/Pragmatist-Sociohistoric tradition, conceptualising learning as becoming attuned to constraints and affordances through participation. This third tradition, essentially the socio-cultural tradition referred to by Koschmann (2001), has become an important influence in studies of ICT in education (see, for example, Crook 1994: Littleton and Light 1998). However, as Greeno et al point out, the idea of thinking skills that transfer from one context to another is highly problematic in the participative paradigm and on the whole this tradition of research has avoided the question of teaching general thinking skills in favour of studies of how learners appropriate local and situated cognitive skills (e.g. Rogoff et al, 1991). The approach of locating thinking skills in types of dialogue that is proposed in this paper and elsewhere (Wegerif, 2004a), could be seen as an attempt to extend the participative paradigm to include a better understanding of how general thinking skills can be taught.

Computer as tutor

The earliest conceptualisation of the role of computers in teaching and learning, saw the computer as a kind of teaching machine able to directly teach not only content knowledge but also some general thinking and learning skills. This conceptualisation, building on the mechanical teaching machines built by Skinner and associated with the work of Suppes (1979) is linked to the behaviourist tradition in psychology. Although it tends to be applied to drill and practice software teaching what Bloom (1956) would call 'lower order' skills such as basic arithmetic, it can equally be applied to teaching what Bloom would call 'higher order skills' such as making effective generalisations. Gagné's instructional design principles recommend breaking down desired learning outcomes into a learning hierarchy with more complex skills resting on simpler skills (Gagné et al, 1992). To support 'transfer' he recommends, for example, providing practice of that skill in a variety of contexts with feed-back and assessment. This approach has been applied directly to teaching general thinking skills using reasoning test problems as the content to be taught (for example, Riding and Powell, 1985)

Computer as providing 'mind tools'.

Papert applied constructivism to the role of computers (1981, 1993) advocating the use of programming and other active modelling environments to support learning (where learning is seen as the active construction of meaning).

Underlying Papert's work is the theory of Jean Piaget and its distinction between 'concrete' and 'formal' thinking. Papert regards the computer experience as a way of making concrete and personal the abstract and formal:

> *… it is not just another powerful educational tool. It is unique in providing us with the means for addressing what Piaget and many others see as the obstacle which is overcome in the passage from child to adult thinking. I believe that it can allow us to shift the boundary separating concrete and formal.*
> (Papert, 1981, p. 21)

This exciting insight inspired many educational technologists and constructivism is probably the dominant paradigm in the design of educational multimedia (Boyle, 1997, p83). The main idea of Jonassen (2000) and others in this tradition, (e.g. Underwood and Underwood, 1990: Salomon et al, 1991), is not that computers will directly teach thinking but that, after working in partnership with computers, the students will internalize the way that computers think as a cognitive tool for their own use.

Computer Supported Collaborative Learning.

In a ground-breaking book entitled 'Understanding Computers and Cognition' (1987) Winograd, one of the leaders in Artificial Intelligence research, and his co-author, Flores, convincingly criticised the view of minds as symbol processing machines like computers. They argued that that computers do not help us think by mimicking human intelligence but that they can support those human practices, particularly communicative practices, in which cognition is embedded. Crook (1994, p 67) argues similarly that computers are not capable of sustaining the kind of intersubjectivity that teaching and learning requires but that they have a potential role in resourcing and supporting collaborative learning. Although their arguments have similarities, they reference different intellectual traditions. It is interesting that Winograd and Flores (1987) refer to Heidegger frequently and Vygotsky not at all while Crook (1994) refers to Vygotsky frequently and Heidegger not at all.

The development of a focus on computer supported collaborative learning (CSCL) has been marked in the last decade with new CSCL societies, conferences and publications. Numerous and varied intellectual sources are referred to by writers who situate themselves in this new CSCL tradition. Koschmann refers to CSCL as a new paradigm in instructional technology research defined through socio-cultural theories of learning (Koschman, 2000), but writers in CSCL also draw on Hermeneutics (e.g Stahl, in press), situated learning theory, distributed cognition, social constructivism, Bandura's social learning theory (Ravenscroft, 2003), phenomenology (McConnell, 2000) amongst other sources.

While some of the claims for the coherence of CSCL as a new paradigm might be exaggerated nonetheless there is clearly a focus on social rather than individual learning that distinguishes this new approach from both the behaviourist and the cognitivist/constructivist traditions that underlay previous approaches to ICT and teaching thinking. Most writers in the CSCL tradition refer to the ideas of educational psychologist Vygotsky to provide intellectual authority for a turn towards the social dimension of learning. Vygotsky is often presented as providing a psychological version of Marx's claim that individual thought is a product of the social and historical context (e.g. Edwards, 1996, p43). In particular Vygotsky claims that language is a tool-system that mediates thought and the development of thought. If language can play the role of a cognitive technology mediating and supporting thought then this implies that so too can other technologies of communication. Vygotsky claimed that the higher mental faculties, including reason and creativity, are internalized versions of forms of social interaction. Some neo-Vygotskians move from this to focus on the forms of interactions themselves as embodying higher order thought (Mercer, 2000). In the CSCL literature the idea of information and communications technology is intimately connected with the idea of teaching thinking in the form of social interactions such as argumentation and collaborative problem solving.

The roots of the enterprise of teaching critical thinking are not necessarily individualist. Dewey, an advocate of teaching thinking, saw thinking as at least in part a product of social interaction and teaching thinking as a way of contributing to the creation of a better society (Dewey, 1933). This is reflected in statements from leaders of the applied teaching thinking movement that locate 'thinking skills' in dialogues and in communities of inquiry (Paul, 1987; Lipman, 2002). Habermas (1991), has argued that rationality implies the ideal of a more genuinely democratic society in which all relevant voices are really listened to and decisions are taken on the basis of convincing arguments rather than on the basis of coercive power. One educational implication of Habermas's argument is that teaching thinking skills involves changing the social context to create conditions that approximate to what he calls an 'ideal speech situation'. There have been a number of claims that the structural properties of CMC, the ease with which anyone can 'take the floor' and the possibility of multiple threading, for example, make it a better medium for an 'ideal speech situation' than face-to-face dialogue (Graddol, 1989; McConnell, 2002). There have also been suggestions that new technology could serve to support better collective thinking in institutions such as schools and in society at large (Selwyn, 2003).

TOWARDS A 'DIALOGIC' PARADIGM

The term dialogic is now used quite loosely for anything pertaining to dialogue in education. This misses an opportunity to make a more radical and useful distinction between truly dialogic and essentially monologic approaches. In the next sections I turn to communications studies and philosophy to outline the true nature and potentially radical significance of dialogic.

The approach to dialogic from communication studies

One source for the dialogical paradigm in the social sciences is the writings of Rommetveit (1992) and Linell (2001) which systematically compare dialogical assumptions with monological assumptions. The monological paradigm, still very much the dominant paradigm in all areas of science, seeks a reduction to a single perspective – its aim is a stable and settled 'truth' in the form of a representation of some kind. Both Rommetveit and Linell argue that, while monologism is clearly very useful in some contexts, it needs to be understood within a deeper and broader dialogical framework. Two key assumptions of this framework can be stated as:

- any communicative act is interdependent with other acts, it responds to what has gone before and anticipates future responses; it is similarly 'in dialogue' with other aspects of context such as the social setting
- meaning does not exist 'ready-made' beforehand but is always constructed in dialogues (which may well be the internal dialogues of thought).

(For a more detailed account of the assumptions of a dialogical paradigm in the context of communication studies see Linell, 1998, p 48)

According to Rommetveit, dialogic means not merely that participants in interactions respond to what other participants do but, more dynamically, that they respond in a way that takes into account how they feel other people are going to respond to them. Rommetveit, quoting Barwise and Perry, refers to this circularity as 'atunement to the atunement of the other' (Rommetveit, 1992). Bakhtin (writing under the name Volosinov) makes a similar point writing that the words of the other 'meet our answering words' and continues that meaning 'is like an electric spark that occurs only when two different terminals are hooked together' (Volosinov, 1986, p 102). Elsewhere Bakhtin sums this up by referring to the 'interanimation' of voices in dialogue (Bakhtin 1986). Bakhtin defined dialogue as 'shared enquiry' but the idea that dialogue is 'like an electric spark' and includes the 'interanimation of perspectives' points to an underlying dialogic principle which challenges common assumptions about the nature of meaning and thinking.

The approach to dialogic from Heideggerian philosophy

The various traditions of teaching thinking tend to provide positive views of thinking which assume a principle of identity which is the common sense principle that things are what they are and not other things. To simplify in order to summarise: for associationists thinking involved links between facts, for cognitivists thinking implied some kind of underlying algorithm and for constructivists it required the building of internal 'cognitive structures'. In his later work Heidegger challenged all of these traditions and offered an alternative view of thinking based not upon identity but upon difference. In a lecture, entitled 'Identity and Difference' (Heidegger, 1969), Heidegger contrasted the principle of identity in the history of western metaphysics, a principle he referred to simply as A=A, with the idea of ontological difference, which he claimed underlay the possibility of there being identity and meaning in the first place. Meaning, Heidegger claims, depends upon an implicit background of assumptions and practices from which things emerge and against which they stand out (This point is brought out well by Gerry Stahl, in press). We only see 'beings' against the background of Being (they are therefore referred to as 'the beings of Being'): we also only know Being as the background Being behind the things that stand out (as 'the Being of beings'). The ontological difference is the difference between beings and Being which brings both into awareness. Merleau-Ponty (1964), a Heideggerian thinker, describes the emergence of meaning in perception as revolving around an invisible hinge between the foreground and the background. In much the same way Heidegger described thinking, by which he meant creative thought or poesis, as the 'circling (ineinander) of Being and beings around one another' (Heidegger, 1969, p 69). Heidegger's term 'ineinander' is translated by Merleau-Ponty as 'mutual envelopment'and illustrated with the example of the horizon that we form around us simply by standing in a landscape: on the one hand the horizon is formed by us out of our perspective, on the other hand we are located within it.

The exciting departure here, one that was picked up by Derrida in his essay 'La Différance' (Derrida, 1968). as well as by Merleau-Ponty in his later work, is the realization that meaning making in general is not a product of identity but of difference. One implication is that meaning depends upon a prior invisible and unnoticed differentiating process that carves out identities. The concept of constitutive difference in Heidegger has been related to the Taoist claim that apparent form is a product of the differentiation of an underlying potential for meaning that in itself is 'empty' or 'an uncarved block' (Lao Tze, 1972, especially chapters 1 and 2). Thinking, for Heidegger, involves not accepting any identity or algorithm but 'stepping back' into the unmediated relation described by the ontological difference and through this stepping back allowing thought to occur as 'emergence' rather than as in any way mechanically caused by a thinker who has an object of thought.

The claim from Bakhtin and Linell that meaning originates in dialogues implies that the space of dialogue, or dialogic space, a space of possibility opened up by an initial difference between two people or two perspectives, is a similar principle to the ontological difference of Heidegger and also to Derrida's closely related concept (or, non-concept or anti-concept) of 'différance'.

A developmental link between dialogue and thinking skills

The claim that dialogic is a version of Heidegger's ontological difference only makes sense if we understand dialogue at two different levels, the surface level of actual dialogues and the underlying level or the dialogic principle which is the original opening of meaning. Empirical dialogues do not necessarily exemplify the idea of an opening of meaning, but they have the potential to question and create because of their intrinsic connection to an underlying dialogic principle. This distinction between surface and depth notions of dialogue can also be understood ontogenetically in terms of the first opening of dialogue in early childhood and a later capacity to engage in dialogues. Hobson argues that babies and toddlers first learn to think through being drawn into a dialogic relationship with their mother, or primary care-giver, which enables them to see things from at least two perspectives at once (Hobson 2002: 1998). Hobson goes on to argue that an individual sense of self-awareness and an ability to think creatively when alone are a product of an internalization of the interanimation of perspectives that occurs in such dialogues (Hobson, 1998). He refers to these dialogues, beginning with peek-a-boo games in the cradle, as opening up what he calls ‘mental space’, a space of possibilities through which things become thinkable.

Hobson’s idea of dialogic as mental space suggests a link between dialogic and thinking skills. Dialogue itself, a capacity to engage in dialogue and to see things dialogically, appears to be the primary thinking skill, a ‘learning to learn’ skill, upon which all other ‘higher order’ skills are dependent and from which they are derivative.

Hobson mainly worked with babies up to 18 months. He also conducted experiments with three year olds which found a link between their IQ scores and the dialogic quality of their relationship with their mothers (Crandell and Hobson, 1999). This relationship between dialogic and IQ relates his work to experimental evidence with nine and ten year old children in primary schools that the quality of individual thinking, measured using Raven’s non-verbal reasoning tests, (a test that correlates well with IQ) can be improved through improving the quality of dialogue in small group work (Wegerif, 2001; Wegerif, Mercer and Dawes, 1999). This experimental evidence, supports the theory that individual thinking skills, even those measured according to the most traditional tests of intelligence, originate in those kinds of dialogues where we learn to open ourselves to creative play and the interanimation of perspectives, and in which we learn to listen and to be responsible to others in dialogues.

Dialogue with social and historical context

While the socio-cultural perspective and activity theory argue that cognition is embedded in social and historical contexts a dialogic perspective would argue that this is only one half of the story. What counts as social and historical context is an interpretation that is created within and through dialogues. One implication of the assumptions of activity theory is that the social and historical context is a relatively fixed framework in which the distinctions pointed to by Engestrom’s analytic triangles (Engestrom, 2001) are always pertinent, distinctions such as ‘subjects’, ‘objects’, ‘tools’ and ‘division of labour’ which describe a Marxist materialist world view. However in creative dialogues people can and do categorise the world in multiple ways and these categories then have an impact on their actions. It is only in and through dialogues that history and culture are given meaning, a meaning that is always open to interpretation. In other words dialogues situate and frame history and culture as much as they are situated and framed by history and culture. This circling or mutual envelopement relationship makes it possible for us to challenge tradition and to create new and different understandings. The dialogic principle presupposes that ideas of space, time, history and culture emerge from distinctions made within dialogues, distinctions such as here/there; now/then; us/them, and so that there is an aspect of every dialogue that is in some way unsituated because it precedes and exceeds every attempt to situate it. It is this opening onto an outside of the system which makes it possible to question, think and be creative in the first place.

Dialogic, thinking and technology

From a Heideggerian or différance informed perspective meaning is a flow within a field (the circling of Being and beings). Words and other mediations of meaning, do not contain meaning in themselves but they structure or articulate the flow of meaning within a field of possible meaning that is opened or catalysed by the opening of dialogue. The dialogic principle can be characterized, in contrast to the principle of identity, as the interanimation of different perspectives where the difference is seen as generative and essential to meaning and therefore as not reducible to identity.

Heidegger expressed concern that technology ‘enframed’ possible experience, ordering everything in advance in a way that could prevent a deep flow of meaning. This critique has implication for how we use communications technology. It is hard, for example, to engage in a truly thoughtful dialogue when every move has to be labeled in advance according to a drop-down menu with a pre-set ‘ontology’ of possible types of thought (e.g Motto et al, 2000). On the other hand many commentators have noted that Heidegger did not do justice to the empowering potential of technology. Pre-set frames can easily appear constraining but can also offer affordances. Providing students with a menu of openers in a synchronous chat forum looks limiting but can actually serve to deepen and enrich dialogue because of the way in which the software interface enters into online social relations, providing a justification and support for challenges and probes that would not have been made otherwise (McAlister et al, 2004).

It follows from the understanding of dialogic and learning dialogues presented above, that methods which attempt to pin down the exact meaning of utterances in a dialogue are misguided because the meaning depends upon a dynamic context of interpretation which can never be completely closed or finalised. Dialogues do not only work through exchanging more or less precise meanings but also through opening up a space of multiple possible meanings. Approaches, sociocultural or otherwise, which refer to computers supporting learning through dialogue without acknowledging the dialogic nature of the creative space opened up by dialogue, remain in danger of a reduction to identity thinking. Some researchers study the learning in dialogues in terms of explicit outcomes resulting from explicit mechanisms as if machines without consciousness or creativity could have learnt equally well from the dialogue as humans. Through a reduction to identity such approaches are clearly not dialogic, they miss the 'opening' that makes thought possible in the first place. Such monologic approaches can work in some respects but they obscure the important possibility that teaching thinking skills is not only about teaching explicit skills but also about deepening and extending dialogue as an end in itself.

A FRAMEWORK FOR TEACHING THINKING WITH CSCL

Although Vygotsky is not a dialogic thinker his account of internalization and externalization suggests a vision of the how dialogues relate to the learning of thinking skills and of how the teaching and learning of thinking skills is part of a larger social movement of dialogue mediated by technology. Vygotsky famously claimed that the development of higher order thinking resulted from an internalization of social interaction. He was also interested in the creative externalization of thought into speech and into the transformation of social contexts. This combination of externalization and internalization is present from moment to moment in a dialogue as we 'take on board' ideas, reformulate and respond to them internally and then express our response in new patterns of signs. It is also true over a larger scale and longer timescale. In any shared enquiry we are not only in dialogue with a dialogue partner, we are also in dialogue with a culture and a tradition.

To picture thinking as a whole circular movement it might help to think of the way that we all, as creative speakers and writers, use words and phrases that we find already here, external to us, in the language around us, and yet we also shape the development of that shared resource of language. Language is a useful example because, following Vygotsky, it is possible to refer to language as a cognitive technology that mediates the circle of thought. If language can be referred to metaphorically as a technology mediating the whole flowing movement of thought the same is more literally true for those information and communications technologies that carry and resource dialogues. The social realm of institutions and culture mediate the whole flowing movement of thinking. This makes the picture of how to intervene effectively to support the learning of higher order thinking complex but it does suggest three possible moments in the whole circle of thought where interventions could be focused, the moment of internalization, the moment of externalization and the moment of mediation. From a Heideggerian perspective these are limited concepts because apparent internalisation is a part of a larger movement of 'implication' in which foregrounds become backgrounds and 'externalisation' is not an individual process but creative emergence from the gap between beings and Being. However the more Vygotskian vision of a transformatory circle of internalization, externalisation and mediation is helpful in making a link between the whole flowing social movement of thought and the teaching of thinking. Most approaches to teaching thinking have focussed on the movement of internalisation when cognitive tools move from the social to become appropriated by the individual. It could equally make sense to support the moment of externalisation when collective thought is creatively transformed or to intervene to improve the cognitive affordances of the technological mediation of shared thinking.

The particular strengths of ICT for education (sometimes called affordances) can be mapped as:

- Speed and Automatic functions: enabling large amounts of information to be handled and routine tasks to be automated
- Provisionality: the ability to change texts and other outputs with minimum cost
- Interactivity: the capacity for feedback and response
- Range: the capacity to overcome barriers of time and distance
- Multi-modality: the capacity to integrate a range of modes of communication including film, graphics, sounds and texts.

(adapted and expanded from Loveless, 2003). A dialogic perspective suggests a number of principles that can be used to guide to the analysis, design and practice of CSCL. In particular it suggests that these features and potentials of ICT can be applied to effectively induct students into dialogues, to deepen and broaden dialogues and to support all stages of the whole circling movement of thought.

Scaffolded induction into dialogues

Provisionality can support reflection and the development of joint ideas through products, including texts and other artefacts, that are not as ephemeral as speech and not as apparently fixed and changeless as print. Interactivity can be used to provide contingent support for dialogues, even the simple prompts, 'what do you think?' and 'why do you think that ?' in the right place can have a profound effect on learning (Wegerif, 2004b).

Interactivity makes it easy for software to simulate multiple points of view in a dialogue thus allowing learners to be inducted into a field of dialogue rather than into fixed 'truths'.

Deepening and broadening

Range and speed allows ICT to expand dialogues to almost every corner of the world and to include almost every perspective on any given question. Broadening can be done through the use of the internet to exchange in real dialogues about global issues. An illustration of this is Oxfams 'tv.oneworld.net site', where video stories from across the world are exchanged and discussed. Broadening in the classroom can be done through structured web-quests where an issue is posed and learners are sent to different web-sites to explore it. With the right pedagogy this broadening potential of internet dialogues also becomes a deepening as students are led to become more reflective and dialogic through the encounter with difference.

Multi-modality

Dialogues consist of a relationship between people or perspectives framing a flow of meaning. This flow of meaning is focused and articulated by signs and communications technologies but not in any way reducible to those signs or technologies. Unlike versions of the socio-cultural perspective which tend to reduce thinking to the use of particular cultural tools, especially concepts and language structures, (e.g Wertsch, 1998) this dialogic understanding provides us with a way to appreciate how different modalities of representation can work together and how different levels and types of dialogue can be integrated into flows of meaning. For example when groups of children talk together to create emails that they send to other groups of children who talk together to interpret them (Van der Meij et al, 2004) then the written email dialogue needs to be interpreted in the light of the oral dialogue. The multi-modal dialogue made possible by ICT with video conferencing and audio conferencing as well as collaborative graphics and music, allows the interesting possibility of dialogic interaction between different representations of meaning as well as between people and perspectives. According to the dialogical paradigm, understanding occurs more through appropriating the gaps between tools than through appropriating the tools themselves.

Internalisation/implication

Vygotsky's idea of how teachers work through a 'zone of proximal development' to help learners acquire new skills refers to the moment of the internalisation by individuals of pre-existing cultural tools mediated by the scaffolding work of tutors. To give an example, the strategy of thinking up a range of alternative possible answers to a problem set could be modelled in group dialogue using concept-mapping, mediated by a tutor, and appropriated by an individual who is then able to use the same strategy alone with and without a physical external concept map (e.g Roth and Roychoudhury, 1994). The concept of implication goes beyond this to also account for embedding into the environment of thinking, for example technologies such as calculators that become ubiquitous and pervasive can augment and develop thinking without internalization of any kind occurring.

Mediation

Although the primary relation between self and other which makes dialogue possible is not mediated the thinking that emerges out of that difference is mediated. Internalisation and externalization, as well as implication and expression, are always mediated, and the affordances of the mediating technology can sometimes be addressed directly as a way of improving the quality of collective thought. The educational technologist can work to improve the affordances for clear and productive thinking provided by the conferencing system or software interface that mediates collaboration. A simple example of this is top provide effective tools for decision making and the shared visualization of relevant information. Once we see thought as not individual or collective but as a larger dialogue or whole flowing movement uniting these two moments then we can see that attention to mediating technologies is also part of teaching thinking.

Creative expression

An individual or group's capacity to participate in shared social dialogues can be supported through the use of technology. There are many ways in which ICT can augment and support creative expression from word-processors through to web-sites. Cobb and McClain illustrate how visualisation tools that allow users to grasp and manipulate complex statistical relationships can empower learners to participate in dialogues about public policy (Cobb and McClain, 2000). This form of empowerment enabling expression and participation, is also a way of improving the quality of individual and collective thinking.

DISCUSSION AND CONCLUSIONS

In 'What calls for thinking' Heidegger writes: 'the proper teacher lets nothing else be learned than – learning.' (1978, p380). This paper is not quite so extreme in its claims. There are many things to learn and many ways to learn them. However the paper does argue that one of the most essential and important things to be learnt, how to learn through engaging in dialogues, has been overlooked. The dialogic understanding of thinking and of learning to think that is sketched in this paper is not intended to replace monologic accounts of thinking and of learning to think but to augment them. Many of the claims about the way ICT can support thinking made in this paper could also be made from constructivist or socio-cultural perspective. However a truly dialogic perspective goes further than these perspectives in providing justifications for the argument that the aim of teaching thinking should not only be the development of specific cognitive techniques and technologies but also developing dialogue as an end in itself. Dialogic has been presented as a principle of non-identity and the inter-animation of perspectives but paradoxically this is a principle that individuals and organizations can learn to identify with more. The extent that individuals and organizations become more dialogic is the extent to which they learn how to learn. The meta-skill of 'learning to learn' is one upon which all other higher order thinking skills depend and from which they are derivative. This paper argues that a dialogic perspective fits with CSCL because the strengths of ICT in education are particularly suited to inducting learners into dialogues and to deepening and broadening those dialogues. The dialogic framework put forward for understanding the relationship between CSCL and teaching thinking suggests that we need to teach dialogue as an end in itself and also that higher order thinking should be understood as a circling movement uniting individual with social thinking, implicit background thinking and explicit signs, and combining different levels and type of dialogue within a flow of meaning. At least three further implications for practice follow from this framework: firstly, that rather than focus only on the moment of internalisation or on the moment of expression or the technological mediation of thought, to teach thinking effectively it is best to support all three moments of the circle of thought in a coherent way: secondly, that to have a maximum impact on the quality of thinking we should look at ways to support the integration of different levels and types of dialogue, perceptual, oral and written modes for example: and thirdly, that we should design for creativity and a resonant relationship with the foreground and background of thought rather than try to use design 'ontologies' that pre-define what can and what cannot be expressed.

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Computer-Supported Collaborative Learning in Higher Education: Scripts for Argumentative Knowledge Construction in Distributed Groups

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Abstract. Learners rarely know how to construct knowledge together in argumentation. This experimental study analyzes two computer-supported collaboration scripts, which should facilitate processes and outcomes of argumentative knowledge construction. One script aims to support the construction of single arguments and the other script aims to support the construction of argumentation sequences. Both scripts were varied independently in a 2×2-factorial design. 120 students of Educational Science participated in the study in groups of three. Results show that the computer-supported scripts facilitate specific processes and outcomes of argumentative knowledge construction. Learners with scripts argued better and acquired more knowledge on argumentation than learners without scripts without impeding acquisition of domain specific knowledge.

Keywords: argumentative knowledge construction, computer-supported collaboration scripts

OBJECTIVES

University students are supposed to become experts within a specific domain. In this regard, students are meant to be able to both understand and participate in argumentative discourse in their field. Even though knowledge on argumentation start to develop from an early age (Stein & Bernas, 1999), studies showed that adults' knowledge on argumentation are often suboptimal (e.g., Kuhn, 1991). Adults hardly base their claims on grounds and rarely consider counterarguments. Even though students may in general acquire domain-specific knowledge, they hardly seem to learn how to argue based on this knowledge within their domain.

An important opportunity for the development of knowledge on argumentation is the active participation in high-quality argumentative discourse in instructional settings (Kuhn, 1991). Regular classroom settings rarely foresee opportunities for learners to engage actively and equally in high-quality argumentative discourse (Cohen & Lotan, 1995). High-quality argumentative discourse in instructional settings means that collaborative learners construct formally and content adequate arguments while jointly working on a learning task. Computer-supported collaborative learning (CSCL) may provide an ideal context for this kind of discourse (Marttunen & Laurinen, 2001). During CSCL, students may construct and exchange arguments online that can be examined and evaluated by learning partners for longer periods of time than in face to face situations. Collaborative learners may thus elaborate the learning material by constructing arguments themselves to promote their perspective on one hand and on the other integrate arguments of their learning partners in their own perspective. In this way, learners may lead a high-quality online argumentative discourse with regard to formal aspects and contents and acquire domain-specific knowledge as well as knowledge on argumentation (see Andriessen, Baker, & Suthers, 2003; Weinberger & Fischer, in press).

The goal of this study is to implement CSCL within a university curriculum of educational science and to investigate how processes as well as outcomes of argumentative knowledge construction can be facilitated by means of computer-supported scripts within this CSCL environment.

ARGUMENTATIVE KNOWLEDGE CONSTRUCTION

Argumentative knowledge construction means that learners construct arguments within a specific domain with the goal to acquire knowledge (Weinberger & Fischer, in press). First, we will portray potential outcomes of argumentative knowledge construction. Second, we will describe the processes of argumentative knowledge construction and how they may facilitate specific outcomes.

Argumentative knowledge construction aims to foster at least two different *outcomes*, namely domain-specific knowledge as well as knowledge on argumentation (Andriessen et al., 2003).

Knowledge on argumentation comprises knowledge on how to construct formally complete arguments with the components claim, ground and qualifier (*knowledge on the construction of single arguments*) and the knowledge on how to construct specific sequences of arguments consisting of arguments, counterarguments and integrations (*knowledge on the construction of argumentation sequences*).

Domain-specific knowledge in the context of this study means to be able to apply concepts from a specific theory that is to be learned. Learners constructing formally and content adequate arguments activate their prior knowledge, elaborate the given learning material, and thus construct new domain-specific knowledge (Andriessen et al., 2003).

The *processes of argumentative knowledge construction* are allocated on at least two dimensions, namely the formal argumentative dimension, regarding the formal structure of arguments and argumentation sequences, and the epistemic dimension, regarding the contents of the single arguments (Weinberger & Fischer, in press).

On the *formal argumentative dimension*, the construction of single arguments and the construction of argumentation sequences consisting of more than one single argument can be differentiated.

A *single argument* has been regarded as a claim which can be supported by grounds and/or specified by qualifier (Toulmin, 1958). Grounds may justify the claim through a warrant. The qualifier limits the validity of the claim. Toulmin's model seems to be feasible to give an account on the quality of single arguments on formal as well as domain-specific levels. Furthermore, the model can be applied in different domains for constructing arguments based on uncertain information. Constructing arguments with these elements facilitates self-explanation of the learning material (Baker, 2003). Self-explanation is supposed to facilitate the integration of new knowledge into existing cognitive structures. Learners prompted to give self-explanations acquired more knowledge than unsupported learners (Chi, DeLeeuw, Chiu, & LaVancher, 1994).

Specific *argumentation sequences* have been regarded as an indicator for the construction of knowledge (Leitão, 2000). First, learners construct arguments to justify their position. This construction of arguments facilitates self-explanation of the learning material (see Baker, 2003). Second, learning partners construct counterarguments to challenge and reconsider these positions. *Counterarguments* facilitate meta-cognitive activities, prompting learners to rethink their initial argument (Leitão, 2000). Finally, learners construct replies and eventually refine the initial positions. By balancing arguments and counterarguments in order to solve complex problems, participants may acquire knowledge on argumentation and domain-specific knowledge.

The *epistemic dimension* regards how learners work on the learning task, what (theoretical) concepts they consider and how they may construct knowledge. Beyond formal aspects of argument construction, the contents learners use to construct arguments supposedly play a crucial role in argumentative knowledge construction (Kuhn, Shaw, & Felton, 1997). It has been found that learners in problem-oriented learning environments need to apply those theoretical concepts, which they are supposed to learn (*application of new knowledge*) in order to acquire domain-specific knowledge (Fischer, Bruhn, Gräsel, & Mandl, 2002; Weinberger, 2003). Beyond applying new knowledge, *application of prior knowledge* has been regarded as important to the acquisition of domain-specific knowledge, e.g., in problem-oriented learning environments of medical education (Schmidt, 1993). The amount of activated prior knowledge is supposed to influence how much new knowledge can be acquired. Students construct meaning by using their prior knowledge in the sense that new knowledge needs to be meaningfully related to existing bodies of knowledge (Anderson & Pearson, 1984).

USING COMPUTER-SUPPORTED COLLABORATION SCRIPTS TO FACILITATE ARGUMENTATIVE KNOWLEDGE CONSTRUCTION

A central topic of CSCL research is how argumentative knowledge construction can be facilitated. Different approaches are being investigated. One prominent approach is *visualization*, which uses software tools and different representations to guide argumentative knowledge construction. Interfaces with different representational aids such as graphs, matrices or texts were found to have different effects on CSCL (Suthers & Hundhausen, 2001). Software tools, may visualize the argumentation of learners (Kirschner, Buckingham Shum, & Carr, 2003). For instance, diagrammatic representations visualize how arguments are related to each other and thus facilitate and guide learners' awareness of the argumentative discourse (Hoppe, Gaßner, Mühlenbrock & Tewissen, 2000). Tools like SenseMaker (Bell, 1997) support learners to represent their arguments by providing spaces and categories to group arguments and differentiate claims from evidence.

Another approach to facilitate argumentative knowledge construction is to realize *computer-supported collaboration scripts* based on O'Donnell's (1999) scripted cooperation approach. Scripts can be implemented into the communication interface of CSCL learning environments as kind of a guideline. They can interactively suggest the next step with a minimal intervention of a teacher. Therefore, the quality of self-regulated learning can be facilitated with a minimum of external regulation. In spite of possible connotations of the term "script", the interface merely suggests learners to construct specific arguments by providing prompts learners should use or respond to (Baker & Lund, 1997; Dillenbourg, 2002; Kollar, Fischer, & Hesse, 2003; Nussbaum, Hartley, Sinatra, Reynolds, & Bendixen, 2002; Weinberger, 2003; Weinberger, Ertl, Fischer, & Mandl, 2005). In this approach, interfaces may be designed to specify and sequence and eventually to allocate different learning activities to learners. Studies show, that computer-supported collaboration scripts may support specific processes and outcomes of argumentative knowledge construction, but may have “side effects” on others (Dillenbourg, 2002; Weinberger et al., 2005). Kollar and colleagues (2003) investigated computer-supported collaboration scripts, which provide text spaces for claims and evidence that learners are supposed to fill as well as a specific sequence of arguments, counterarguments and integrations. Whereas learners acquired domain-specific knowledge independent of the script support in this study, computer-supported collaboration scripts facilitated knowledge on argumentation as an outcome of argumentative knowledge construction. Against this background, scripts can be conceptualized that facilitate the construction of a single argument according to Toulmin’s model (1958) and scripts that facilitate the construction of argumentation sequences according to Leitão (2000). A script for the construction of single arguments should facilitate the relative frequency of grounds that support a claim while a script for the construction of argumentation sequences should foster the relative frequency of counterarguments. Both scripts should support learners to apply concepts from prior knowledge to problems (application of prior knowledge) as well as the new theoretical concepts they are supposed to learn (application of new knowledge).

RESEARCH QUESTIONS

There is little knowledge whether computer-supported collaboration scripts that specifically aim to support the construction of single arguments and argumentation sequences may foster the formal argumentative and / or the epistemic dimension of argumentative knowledge construction. Based on this, the following two research questions are examined:

- To what extent does a script for the construction of single arguments and a script for the construction of argumentation sequences and their combination, influence the processes of argumentative knowledge construction on the formal argumentative and the epistemic dimension?
- To what extent does a script for the construction of single arguments and a script for the construction of argumentation sequences and their combination, facilitate the outcomes of argumentative knowledge construction, namely domain-specific knowledge and knowledge on argumentation?

METHOD

Sample and Design

One hundred twenty students of educational psychology participated in this study. The experimental learning environment was part of a regular curriculum. The students, who were attending a mandatory introduction course, participated in an online learning session as a substitute for one regular face to face session of the course. Participation was required in order to receive a course credit at the end of the semester. The learning outcomes of the experimental session, however, were not accounted for in students’ overall performance. The participants were separated into groups of three and each group was randomly assigned to one of the four experimental conditions in a 2×2 factorial design. We varied (1) the script for the construction of single arguments (without vs. with) and (2) the script for the construction of argumentation sequences (without vs. with). Time on task was held constant in all four conditions.

Learning environment in the different experimental conditions

The subject matter of the learning environment was Weiner’s attribution theory (1985). A three-page description of this theory was handed out to the students. Three learning cases were used as a central component of the learning environment. Each case was authentic and complex and allowed learners to construct different arguments based on theoretical concepts of the attribution theory. One case, for instance, asked to interpret school performance differences between Asian and American/European students with the attribution theory.

Three students worked together, but were placed separately in one of three different laboratory rooms. The group’s task was to analyze the three cases in an 80-minute collaboration phase and to provide a joint solution of the case. A problem-oriented learning environment, developed for asynchronous, text-based collaboration was used. The implemented newsgroup tool was used to exchange email-like text messages. In addition, the environment allowed for implementing different types of computer-supported collaboration scripts.

(1) The *control group* received no additional support in solving the three problem-cases.

(2) The *script for the construction of single arguments* is implemented in the interface as a given text structure within the individual messages and aims to support learners in the formation of single arguments. The script, based on Toulmin's model (1958), differentiates between claim, ground with warrant and qualifier and is realized by text windows in the interface of the CSCL environment (see figure 1). The learners were asked to fill out each text window of the interface to construct a complete single argument. After building the argument, the single argument would be added with a click to the message body. Non-argumentative parts of the message, like questions, could be added directly to the message body, without using the argument construction interface.

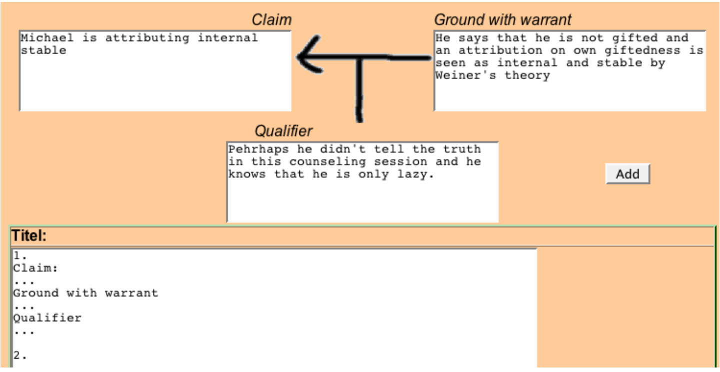

Figure 1. The interface of the script for the construction of single arguments.

(3) The *script for the construction of argumentation sequences* aimed to facilitate a specific argumentation sequence of argument-counterargument-integration (following Leitão, 2000). The subject of the posted message was automatically pre-set, depending on the position in the cascading discussion thread. Each first message of a discussion thread was labelled "argument". The answer to an argument was automatically labelled as counterargument and a reply to a counterargument was labelled as integration. The next message was again labelled counterargument, then integration and so on. In this way, there was a default path through the discussion according to the Leitão model (see figure 2). The learners could change the subject of their message if necessary.

(4) In the *combined condition,* the learners are supported with both scripts during collaboration. The interface contains the three fields for argument construction and subjects of the messages are pre-set automatically by the script for the construction of argumentation sequences.

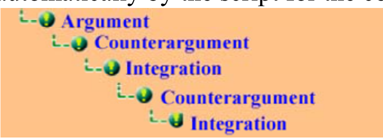

Figure 2. Discussion thread guided by the script for the construction of argumentation sequences.

Procedure

First, pre-tests served to determine prior domain-specific knowledge, knowledge on argumentation and experience with CSCL environments. The pre-tests were used to control randomization. Subsequently, the participants were asked to study individually the three-page description of the attribution theory for 20 minutes. Learners were then introduced to the learning environment. Afterwards, the learners collaborated for 80 minutes in groups of three to work on the learning cases and to agree on case analyses. In the final phase (about 45 minutes), the students took individual post-tests on domain-specific application-oriented knowledge regarding the attribution theory and knowledge on argumentation tests.

Data sources and instruments

Processes and outcomes of argumentative knowledge construction have been analyzed with an instrument described in Weinberger and Fischer (in press). Trained coders segmented the discourse corpora into propositions and rated the segments on the epistemic dimension with regard to application of prior knowledge and application of new knowledge and on the formal process dimension of argumentative knowledge construction with regard to the construction of single arguments and the construction of argumentation sequences. With respect to segmentation, the coders achieved an agreement of 83%. The median of the Kappa values for categorizing the epistemic dimension was sufficiently high with $\kappa = .72$ as well as for the formal argumentative dimension ($\kappa = .61$).

Process variables

On the formal argumentative process dimension of argumentative knowledge construction, grounds as well as counterarguments have been coded. Grounds are reasons given in support of a claim. Grounds can come in form of facts, statistics, expert opinions, examples, explanations and logical reasoning. In the context of this study, learners may support claims with case information or concepts from the given attribution theory. Indicators for grounds that support claims are prepositions such as "because", "due to the fact" etc. even though learners may not always explicitly connect grounds to the respective claims. For instance, if the claim, "Asian attribution patterns are typically superior" is based on the ground "Asians typically ascribe failure to a lack of efforts rather than a lack of talent", this last phrase has been coded as one ground. The percentage of grounds has been calculated in comparison to other components of single arguments (simple claims, qualifiers, and non-argumentative moves such as questions). A high share of grounds indicates high-quality argumentative discourse with respect to the construction of single arguments.

Regarding the construction of argumentation sequences, the percentage of *counterarguments* was calculated in comparison to other argumentative moves within an argumentation sequence (arguments, integrations, and non-argumentative moves). Counterarguments are arguments that oppose another argument. The opposition of arguments has been assessed on the basis of differences of claims. If one claim contradicts a preceding claim, the later claim is being coded as counterargument. For instance, the argument "The teacher is supporting his pupils in adjusting the task difficulty to their individual skill levels" can be countered by the argument "The teacher is not supporting the pupils in adjusting the task difficulty (because adjusting task difficulty can be based on a dysfunctional attribution of the teacher)". Counterarguments are typically expressed by another learner than the one who made the initial claim. Learners may, however, also construct counterarguments to their own arguments.

On the epistemic dimension, both the *application of new knowledge* and the *application of prior knowledge* have been focused on. With regard to the *application of new knowledge*, any unit of analysis has been coded that contains a relation of a theoretical concept from the given attribution theory to case information. For instance, the case information "Michael says he is not talented for maths" is explained with the following theoretical concept in the phrase "this indicates that Michael attributes his failure in maths to internal stable causes". When learners explain case information with concepts that do not stem from the given attribution theory, they *apply prior knowledge* to case information, e.g., the case information "Michael says he is not talented for maths" is considered in "Michael is just plain lazy – he needs to acquire learning strategies and discipline".

The processes on the formal argumentative and the epistemic dimension will be illustrated in a single case study based on a segment of a discussion thread that has been supported with the script for the construction of argumentation sequences. The segment will indicate the single messages, their titles, authors (with fictional names), and their position in the cascading discussion thread. Each message will be analyzed for the above process categories on the two dimensions, namely with regard to grounds, counterarguments, application of new knowledge and application of prior knowledge.

Outcome variables

In order to measure *domain-specific knowledge*, participants had to individually analyze a new case. The written analyses of the participants were segmented into propositions and coded with respect to adequate applications of theoretical concepts of the attribution theory. The number of these propositions that the individual learners were able to construct was counted by five trained coders (κ = .72) and served as indicator for the acquisition of domain-specific knowledge.

In the *knowledge on argumentation test* the participants had to recall components of single arguments and argumentation sequences. Furthermore, participants were asked to formulate arguments about "smoking" in the knowledge on argumentation test. The arguments that learners built were analyzed with respect to the components of single arguments (claim, ground, and qualifier). The argumentation sequences that learners built were analyzed with respect their function as argument, counterargument, and integration. Thus, *knowledge on the construction of single arguments* and *knowledge on the construction of argumentation sequences* were differentiated. Two trained coders rated the knowledge on argumentation test (κ = .83).

RESULTS

Research Question 1 on processes of argumentative knowledge construction

First of all, the effects of the two computer-supported collaboration scripts and their combination on the processes of argumentative knowledge construction were examined. This includes the effects of the two scripts on the formal argumentative dimension and the effects of the scripts on the epistemic dimension.

With respect to the *formal argumentative dimension* the scripts produced the following specific effects on the relative frequency of *grounds* (see table 1 for percentage of grounds). The script for the construction of single arguments increases the percentage of arguments based on grounds substantially and strongly ($F_{(1, 36)}$ = 21.24; $p < .05$; $\eta^2 = .37$). The script for the construction of argumentation sequences shows no effect on the percentage of grounds ($F_{(1, 36)} = 0.02$; *n.s.*). No interaction effect of both scripts could be found ($F_{(1, 36)} = 0.91$; *n.s.*).

Both scripts influenced the percentage of *counterarguments* (see table 1). The script for the construction of argumentation sequences strongly affected the percentage of counterarguments ($F_{(1, 36)} = 9.08$; $p < .05$; $\eta^2 = .20$) positively, as did the script for the construction of single arguments ($F_{(1, 36)} = 7.14$; $p < .05$; $\eta^2 = .17$). The two scripts did not interact with regard to the percentage of counterarguments ($F_{(1, 36)} = 1.23$; *n.s.*).

Table 1. Formal argumentative dimension by experimental group: Mean percentages and standard deviations of grounds and counterarguments.

	Grounds		*Counterarguments*	
Experimental group	*M*	*SD*	*M*	*SD*
Control group	12.08 %	11.48	2.46 %	3.67
Script for the construction of single arguments	33.80 %	11.19	5.36 %	8.07
Script for the construction of argumentation sequences	16.36 %	17.78	5.99 %	3.95
Combined condition	30.64 %	6.10	13.00 %	6.59

The computer-supported collaboration scripts also affected the *epistemic dimension* (see table 2). With regard to the *application of new knowledge*, the script for the construction of single arguments produced a negative effect ($F_{(1, 36)} = 5.47$; $p < .05$; $\eta^2 = .13$). Neither a main effect of the script for the construction of argumentation sequences ($F_{(1, 36)} = 1.91$; *n.s.*) nor an interaction effect of both scripts on application of new knowledge could be found ($F_{(1, 36)} = 0.00$; *n.s.*).

The script for the construction of argumentation sequences significantly and strongly increases the *application of prior knowledge* ($F_{(1, 36)} = 11.24$; $p < .05$; $\eta^2 = .24$). Neither a main effect of the script for the construction of single arguments ($F_{(1, 36)} = 0.00$; *n.s.*) nor an interaction effect of both scripts could be found ($F_{(1, 36)} = 0.90$; *n.s.*) with respect to application of prior knowledge.

Table 2. Epistemic dimension by experimental group: Means and standard deviations of application of new knowledge and application of prior knowledge.

	Application of new knowledge		*Application of prior knowledge*	
Experimental group	*M*	*SD*	*M*	*SD*
Control group	7.97	3.45	13.80	7.93
Script for the construction of single arguments	5.07	3.75	16.80	8.52
Script for the construction of argumentation sequences	6.23	4.16	27.00	12.78
Combined condition	3.43	4.03	24.20	8.72

Both scripts successfully facilitated the specific processes of argumentative knowledge construction they aimed at. Supported with the script for the construction of single arguments, the percentage of grounds doubles, but still only one third of the claims is supported with grounds. Both scripts double the share of counterarguments, but typically learners do not construct counterarguments, but argue in favor of one claim only. Both scripts seem to have specific “side effects” on the epistemic dimension. Learners with the script for the construction of single arguments less frequently show applications of new knowledge and learners with the script for the construction of argumentation sequences show applications of prior knowledge more frequently than learners without scripts. In order to illustrate these effects on the epistemic and formal dimension of argumentative knowledge construction simultaneously, a discourse segment of a learning group supported by the script for the construction of argumentation sequences is presented next. This discourse segment has been selected to illustrate a discourse with a high frequency of application of prior knowledge.

The learning case that the learners work on in this example is about a pupil who is afraid not to make mathematics class next year, because he thinks he is not talented for this subject (internal stable self-attribution). His parents equally attribute their son’s failure on lack of talent (internal stable attribution of others), whereas his teacher ascribes his failures to a lack of efforts (internal variable attribution of others). In the learning group of three, 32 messages in two threads have been sent to discuss and analyze this case. This means that two "argumentation" messages have been followed by 17 messages automatically labeled "counterargument" and 13 messages automatically labeled "integration". The participants did not replace or modify any of the automatically set subjects of the messages. Eight messages from one of the discussion threads have been selected for the example illustration.

(1) Karin: **Argument**
If you think that you are not talented for math, you have little chance for success!

(2) Karin: **Counterargument**
What do you think? Can you compensate lack of talent by learning?

(3) Ella: **Integration**
I think you may compensate lack of talent momentarily by learning, than you will forget what you have learned, because you are happy that you are done with learning.

(4) Karin: **Counterargument**
But you can learn in order to improve your performance, can't you?

(5) Ella: **Integration**
Yes, but math is one of these subjects you can drill and practice, but only with the help of others, because when you are learning all alone you lack certainty all of a sudden, you get scared and you don't know right from wrong anymore.

(6) Karin: **Counterargument**
That's right, you might need help for learning, maybe friends who know their stuff better than you. But you still can learn!

(7) Ella: **Integration**
Yes, he has to be at home and learn, but certainly only as a "MUST" – he won't have fun.

(8) Karin: **Counterargument**
You may be more successful with fun things. But how many things that need to be learned are fun to do?

Figure 3. Schematic representation of a segment of one of the discussion threads from an example discourse that has been supported by the script for the construction of argumentation sequences.

In this example (see figure 3), the first message (1) of Karin labeled "Argument" is a short explanation of the learning case which can be categorized as application of new knowledge, because the attribution theory states that the attribution for failure on lack of talent decreases chances for success. Ignoring the label "Counterargument", the same learning partner, Karin, continues the discussion thread and (2) replies to herself with a message containing questions that point beyond analyzing the case with the attribution theory. Karin's learning partner, Ella, (3) replies to that in a message labeled "Integration" and constructs a claim that is supported by a ground, but shows application of prior knowledge rather than analyzing the case with adequate concepts from attribution theory. Karin (4) replies with a message labeled "Counterargument". Her message actually contains a counterargument (without grounds and qualifiers) to Ella's claim that learning compensates lack of talent only momentarily, but Karin does not return to analyze the case with new knowledge, but rather discusses other aspects of the learning case and applies prior knowledge. Another (5) message labeled "Integration" from Ella follows. However, this message is actually rather a counterargument then an integration. On the epistemic dimension, Ella does not apply new knowledge, but yet again introduces new aspects (application of prior knowledge), namely instructional approaches towards the subject mathematics. Karin's (6) message "Counterargument" again actually contains a counterargument. On the epistemic dimension, she also applies prior knowledge. Ella then (7) turns to other motivational approaches (application of prior knowledge) to make her point that learning is of little help in this case, but again does not refer to the theory which is to be learned. Her "Integration" message can be coded as counterargument. Karin finally (8) notes that motivation is important for learning, but not sufficient to explain performance differences in different subjects (application of prior knowledge). In opposing Ella, Karin constructs a counterargument.

First of all, it can be noted that learners apply an argument-counterargument sequence. The learners do not always respond to the given labels of their messages in the intended manner, e.g., they construct a counterargument even if their message has been automatically labeled “integration”. Learners do not always follow the prescriptions of the script for the construction of argumentation sequences. But as the results show, the computer-supported collaboration scripts still affect the processes of argumentative knowledge construction in the intended direction.

With regard to the formal argumentative dimension, Ella claims that learning may not improve performance, which she supports with various grounds (messages 3, 5, and 7). Karin constructs the counterargument that learning may improve performance (messages 4, 6, and 8). With regard to the epistemic dimension, the participants appear to wander off the actual task to analyze the case with the help of concepts from attribution theory (application of new knowledge). Instead, learners apply prior knowledge starting with the second message of this discussion thread. Karin is asking the question which leads learners to discuss their epistemological beliefs on the efficacy of learning.

Research Question 2 on outcomes of argumentative knowledge construction

In order to answer research question 2, the influence of the two computer-supported collaboration scripts on the *outcomes* of argumentative knowledge construction, namely domain-specific knowledge and knowledge on argumentation was examined.

Neither the script for the construction of single arguments ($F_{(1, 36)} = 0.33$; *n.s.*), nor the script for the construction of argumentation sequences ($F_{(1, 36)} = 0.08$; *n.s.*), nor the interaction of both scripts ($F_{(1, 36)} = 1.27$; *n.s.*) facilitated *the acquisition of domain-specific knowledge*. Learners of all four experimental conditions did not differ with respect to the acquisition of domain-specific knowledge.

Knowledge on argumentation could be specifically facilitated with the scripts.

Table 4. Outcomes of argumentative knowledge construction by experimental group: Means and standard deviations of domain-specific knowledge and knowledge on argumentation.

	Domain-specific knowledge		*Knowledge on the construction of*			
			single arguments		*argumentation sequences*	
Experimental group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Control group	4.33	2.16	3.08	1.08	2.23	1.65
Script for the construction of single arguments	4.70	1.49	4.17	1.55	2.03	1.69
Script for the construction of argumentation sequences	4.90	2.52	2.70	1.21	5.25	1.05
Combined condition	3.77	2.12	4.78	0.75	4.55	0.85

The script for the construction of single arguments strongly facilitated *knowledge on the construction of single arguments* ($F_{(1, 36)} = 17.97; p < .05; \eta^2 = .33$), whereas no effect of the script for construction of argumentation sequences ($F_{(1, 36)} = 0.10$; *n.s.*) nor an interaction effect of both scripts could be found ($F_{(1, 36)} = 1.79$; *n.s.*).

The script for the construction of argumentation sequences strongly facilitated *knowledge on the construction of argumentation sequences* ($F_{(1, 36)} = 41.50; p < .05; \eta^2 = .54$), whereas no effect of the script for the construction of single arguments ($F_{(1, 36)} = 1.10$; *n.s.*) nor an interaction effect of both scripts could be found ($F_{(1, 36)} = 0.39$; *n.s.*).

Although all experimental groups acquired a similar amount of domain-specific knowledge, both scripts successfully facilitated the acquisition of knowledge on the construction of single arguments or the construction of argumentation sequences. The learners were able to construct single arguments and argument sequences depending on what the computer-supported collaboration script aimed at. The scripts did not interact and can be combined to foster knowledge on the construction of single arguments as well as knowledge on the construction of argumentation sequences at the same time.

CONCLUSIONS

Computer-supported collaborative learning can be realized in the curriculum of university studies and facilitated with computer-supported collaboration scripts. Compared to traditional classroom settings, students can thus be encouraged to actively construct arguments (cf. Cohen & Lotan, 1995; Weinberger, 2003). Potential settings for CSCL in university lectures could be that learners build small groups and work on problems together via the internet. Computer-supported collaboration scripts can facilitate specific processes and outcomes of argumentative knowledge construction of students in higher education. The analysis of the formal argumentative dimension of the discourse within the learning groups of the control condition showed in line with other studies (Kuhn, 1991; Kuhn et al., 1997), that learners hardly base their claims on grounds and hardly construct counterarguments. The computer-supported collaboration scripts showed that they can improve the argumentative discourse quality of students. Scripts could be integrated into a CSCL environment and proved to facilitate the percentage of grounds and counterarguments that learners construct in argumentative discourse. Thus, the scripts improved the formal argumentative dimension and influenced the epistemic dimension of argumentative knowledge construction. Learners with the script for the construction of single arguments did not as frequently engage in the application of new knowledge as learners without the script. The script for the construction of argumentation sequences facilitated the application of prior knowledge. Computer-supported collaboration scripts may activate prior knowledge and facilitate learners to come up with alternative explanations. An explanation for the pattern of results with respect to the processes of argumentative knowledge construction is that the scripts provided a structure that defined the activities of the learners with respect to the formal argumentative dimension, but shifted the focus of learners away from the question with what kind of content this structure is supposed to be filled. Thus, learners may have been more concerned to satisfy the affordances on the formal argumentative dimension than on the epistemic dimension. Learners were challenged to find grounds and counterarguments, but not supported with respect to the question on what contents these grounds and counterarguments should be based on. Therefore, the prior knowledge may have been more easily available to learners to apply than the new knowledge concepts that were to be learned.

In line with other studies (e.g., Kollar et al., 2003), the scripts facilitated knowledge on argumentation on the specific levels they were aiming at, but did not facilitate domain-specific knowledge. Assumptions that the construction of arguments also leads to the acquisition of domain-specific knowledge through elaboration of the learning material cannot be fortified (Baker, 2003). An explanation for this is that learners supported with the scripts focused on the construction of arguments, but may have based their arguments rarely on new knowledge, which has been found to be related to acquisition of domain-specific knowledge (Weinberger, 2003). It can be assumed that parts of these results can be traced back to the specific effects of the scripts on the processes of argumentative knowledge construction. Therefore, future scripts might need to foster both the formal argumentative and the epistemic dimension of argumentative knowledge construction in order to facilitate students to learn to argue on a general level as well as within their domain. There are indications, however, that knowledge on argumentation may foster acquisition of domain-specific knowledge in the long run (see EUROSCALE project at http://www.euroscale.net; Kollar et al., 2003). In reference to this prior work, the scripts applied in this study may be an apt instructional method to foster knowledge on argumentation in CSCL environments and future argumentative knowledge construction scenarios.

Knowledge on argumentation is important for lifelong learning and should be further developed (Andriessen et. al., 2003; Linn & Slotta, 2000). Based on this study, consequences for practitioners as well as researchers can be drawn. In the educational practice of universities, specific scripts in problem-oriented environments may endorse argumentation trainings. Scripts for argumentative knowledge construction can activate prior knowledge of learners and facilitate acquisition of argumentative knowledge without impeding acquisition of domain-specific knowledge. The study has also shown that CSCL environments could endorse university curricula and thus change educational practice. Teachers or coaches can integrate computer-supported scripts into ongoing collaboration processes with little additional effort. With regard to future CSCL research, there is a lack of studies on computer-supported collaboration scripts in field settings like classrooms or university lectures in different domains. Additionally, we need to further investigate the combination of script components with different goal dimensions, e.g., scripts that also facilitate the epistemic dimension of argumentative knowledge construction (Weinberger et al., 2005). We therefore suggest systematizing the effects of computer-supported collaboration scripts in universities. An important step in making scripts available and applicable in different university departments is to formalise script components that aim at specific aspects of argumentative knowledge construction. Computer-supported collaboration scripts may thus support specific forms of argumentative discourse within different domains and CSCL may become an endorsement to argumentative knowledge construction in higher education.

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Macroscopic Study of the Social Networks Formed in Web-based Discussion Forums

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Abstract. It is proposed and outlined in this paper on how to investigate the macroscopic features of those large-size social networks formed in web-based discussion forums. Some preliminary results on the pattern of the distribution of replies for individual topics, views for individual topics and co-discussants of individual participants will be presented. The present results will be compared with those found in other areas of large-size social networks and the significances and future work on those macroscopic properties of social networks for better understanding of computer-supported collaborative learning will be discussed.

Keywords: Social Network Analysis, Web-based Discussion Forum, Computer-Mediated Communication

INTRODUCTION

Since mid1990s, social network theory (see, e.g. Wasserman and Faust, 1994; Degenne and Forse, 1999; and Batten, Casti and Thord, 1995) has been employed by a number of researchers to analyze students' interaction and learning in various computer-supported collaborative learning (CSCL) environment as facilitated by different kinds of computer-mediated communication systems in several university programs. Although most of those prior network analyses (see, e.g. Haythornthwaite, 1998; Palonen and Hakkarainen 2000; Cho, Stefanone and Gay, 2002; Martinez et al., 2003; and Aviv, Erlich and Ravid, 2003) were very intensive, were established in varied settings and were often coupled with qualitative data as collected from face-to-face interviews for triangulation of their results, yet one serious limitation of their work comes from the fact that the size of their networks under investigation is usually very small (ranging from a dozen to a hundred only). This shortcoming will not only cast doubt on the accuracy and general validity of their results but also prevent them from studying many significantly important macroscopic features of social networks such as identification of the network type, distributions of various network properties, formation of giant cluster and percolation phenomena etc which have attracted extensive research interest by many researchers on different types of social networks (e.g. the Internet, the World Wide Web, phone call networks, citation networks, research collaboration networks, country roadmaps, airline routing networks, electricity transmission networks, spread of AIDS and the food web) in the last few years (see, e.g. Albert and Barabasi, 2002; Buchanan, 2002 and Watts, 2003).

There are several key channels such as web-based/online discussion forum, email, ICQ/chat room, NetMeeting (or equivalent GnomeMeeting in Linux/Unix systems), phone call, scheduled/unscheduled face-to-face discussion which are usually found or adopted in many CSCL environments. Online discussion forum is specifically chosen for the present study because by default it can record almost all the participants' communication information and the messages themselves can readily be retrieved for content analysis without additional efforts for hardware or software modification. Furthermore, Haythornthwaite's (1998) study on the growth of community among distance learners revealed that web-board was the most popular (with nearly 100% usage) channel of communication adopted by those distance learners enrolled for a master degree in his university.

IDEAS AND METHODOLOGY

First of all, we can construct two kinds of social network from a web-based discussion forum. It is known that the mathematical description of a network is a graph (Wasserman and Faust, 1994; and Yeung, Liu and Ng, 2005) which is denoted by $G(\mathbf{N}, \mathbf{R})$, where **N** is the set of nodes or actors and **R** is the set of relationships or links between these nodes. In a given discussion forum, there is a set of participants **P** who post the set of messages **M** in it. Hence, an obvious network for the discussion forum can be formed by taking **P** and **M** altogether as the node set, i.e. **N** = {**P**, **M**}. The relationship set **S** is imply "who submits/posts that message" and this links up individual elements in **P** with one or more elements in **M**, i.e. a one-to-many mapping from P to M because one participant can post many messages in the discussion forum. It is noted that we exclude multi-authorship by treating the one who posts the message as the sole node in our network but unlike research publications, multi-authored messages are rather rare in discussion forum. Let us call it the *basic network* $G_B(\{\mathbf{P}, \mathbf{M}\}, \mathbf{S})$ and it is obviously a kind of bipartite graph (Wasserman and Faust, 1994) in which there is no link or relationship given to relate elements within the set **P** or within the set **M**. Can we have an objective way to provide the linkages amongst certain elements within the set **P**? And what are the significances or implications of studying those linkages for the understanding of CSCL?

To answer the questions raised in the last paragraph, we shall borrow the idea of research collaboration from Newman (2001) who has constructed several very large-size (up to 1.5 million nodes) collaboration networks of researchers in various major fields of science by identifying two researchers as "socially linked" if they have published at least one paper together. In an online discussion forum, there is a topic starter who raises a question, announces a message or expresses his/her view on a certain issue and this forum message may be subsequently replied by one or more forum participants. Those followers and the original topic starter can all be treated as "socially linked" because they have mutually exchanged ideas, shared information or learnt from the peers (there are of course some rare cases that the topic starter never returns to view the follow-up messages). Therefore, a second kind of network called the *collaborative learning network* $G_C(\mathbf{P}, \mathbf{M}_S)$ can be constructed by taking the forum participants **P** as the set of nodes and the relationship set consists of all the submission of messages $\mathbf{M}_S$ to individual topics for indicating the co-discussion of a particular topic by various participants.

Based on the afore-mentioned conceptual framework and the usual social network theory, the following procedures have been adopted to construct both the basic network G_B and the collaborative learning network G_C for groups of online discussion forums:

1. Retrieve the forum participant's name (maybe nickname) from every message of a chosen forum and put all names for a particular topic in the same line (separated by a certain delimiter) to implicitly denote their relationships. A special Windows-based program called the "HAS Centre Browser" (available from the author) has been developed to provide the capability to complete this task automatically while the researcher uses it to browse the online forum. Some other relevant information such as the number of views for a given topic can also be retrieved by this program.
2. Participants' names from all topics of one or a group of forums are combined into a single file, sorted and duplicates eliminated and re-labeled with unique sequential numbers. This step can be done by using the MS Excel program.
3. Participant names in the original computer files for Step 1 above are then converted into the unique number labels as given in the Step 2. A small program has been developed to accomplish this task so that the data will be given in a format suitable for input by other social network analysis computer programs.
4. Two powerful and well-known shareware/freeware programs called UCINET (Borgatti, Everett and Freeman, 2002) and PAJEK (Batagelj and Mrvar 1999) for social network analysis can be used to extract various network statistics and draw the corresponding network graphs for providing a macroscopic view of the complex networks.

As an initial study, a public website called Linux Forum (http://www.linuxform.com/forums/) is chosen because the forums inside are very well-documented and are provided with many useful statistics. Unlike the Microsoft Windows, Linux is an open-source operating system which has rather little official technical supports and so peer support and collaborative learning are very essential in building up the knowledge base. On the other hand, authors need to register with a unique login name before they are allowed to post messages in any forum and this can effectively eliminate the problem of misidentification of forum participants. There are some moderators present to keep the forum discussions evolving in a proper manner and the content analysis of some randomly selected messages inside many forums of this website reveals that most forum participants are very professional in attitude and most of their messages do contain meaningful and useful knowledge and experiences for peer sharing or collaborative learning.

RESULTS AND DISCUSSION

For the Linux Forum website mentioned above, the HAS Centre Browser was used to retrieve messages from 36 forums (grouped under 6 main areas) during the period of the first two weeks in Nov., 2004. As extracted from all those messages, there were in total 24,384 topics which were followed by 51,724 replies and 53,070 counts of participant names. Four areas of forums, namely Linux Forum, Miscellaneous, Linux News Discussions and Rants were excluded from our study because their themes are either not directly related to the collaborative learning or sharing of knowledge on the Linux systems or they are read-only archives copied from other Usenet groups.

Figure 1 shows a semi-log pilot for the frequency distribution of the number of replies for individual topics posted in all the 36 forums under study. The greatest number of follow-up replies for a particular topic is 148. Since most topics were followed by 30 or less replies, the sparsely distributed data for higher number of replies were truncated from Figure 1. As most data nearly fall along a straight line, this set of data is very likely to follow the *exponential distribution* which is commonly found in the medical and industrial engineering field. For instance, the life span of a person or of an engineering product follows this kind of "memoryless" right-skewed distribution whose probability density function has the *form* $p(k) = \lambda \exp(-\lambda k)$ where the parameter $\lambda = 0.266$ yields the best fitted straight line in Figure 1. This result implies that a given topic started in any forum is most likely unreplied at all and on average there are $1/\lambda = 3.76$ replies. In research collaboration networks, the degree of co-authorship (number of authors per paper) and the degree collaboration (number of collaborators per author) also follow this exponential distribution (Yeung, Liu and Ng, 2005).

Since there are many people who simply want to find answers (or passively learn without sharing or mutual communication) from other forum participants' conversation, Figure 2 shows the frequency distribution of views for all messages posted around a given topic. After some critical examination, it is discovered that those data actually follow a *lognormal distribution* with the form $p(k) = \dfrac{1}{k \cdot S\sqrt{2\pi}} \exp(-{(\ln \cdot k - M)^2}/{2S^2})$ where $M = 4.3$ and $S = 0.92$ yield the best fitted "bell-shape" curve. This is a new kind of network distribution which has not been identified by any previous researchers in most well-known large-size networks even though lognormal distribution is quite commonly used to describe various biological, social and economic phenomena. This result means that for each group of messages posted around a given topic of this Linux Forum website, there were in total most likely viewed ($\exp(M+S^2/2)$ =) 113 times or in average ($\exp(M-S^2)$ =) 32 times by other people. However, we must be aware that the number of views per topic will naturally grow with time and be cautious in our interpretation that one or more search engines (e.g. Google) are scanning through all messages at regular time intervals and their activities are recorded in the view count of this forum, yielding a same rate of growth for the view count in every messages posted. Further investigation will be required to uncover and explain for the occurrence of this kind of distribution.

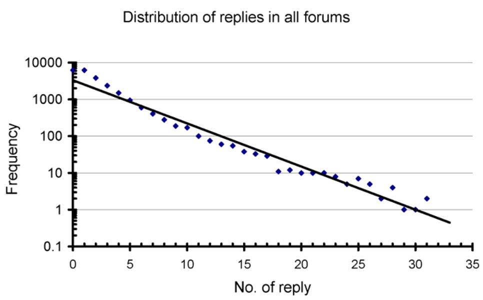

Figure 1: Frequency distribution of follow-up replies for a given topic posted.

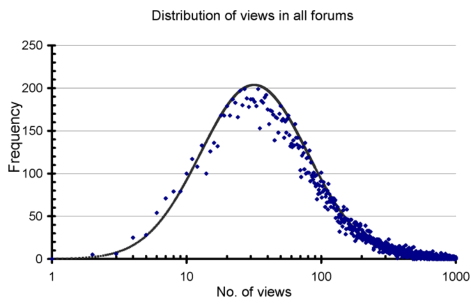

Figure 2: Frequency distribution of views for messages posted around a given topic.

To study the interaction between forum participants, we need to employ the UCINET and PAJEK software to carry out the very time-consuming and memory intensive computation. As an initial analysis, a smaller collaborative learning network G_C was constructed for 4 forums in the General Linux Issues area which contains 9,327 topics with 3,214 different participants in total. Figure 3 shows a log-log plot for the frequency distribution of co-discussants of individual participants. Co-discussants are defined to be those who have ever posted messages for a certain topic. These data could reveal many useful characteristics such as centrality, social roles, cohesion, and cluster formation of a social network. For this short paper, we just present one key result – the data follows a power-law form distribution $p(k) \sim k^{-n}$ where the power-law exponent $n = 1.20$ for the best fitted straight line given in Figure 3. Power-law form distribution is a characteristic form of the so-called "scale-free" network (Albert and Barabasi, 2002) which is commonly found in many other kinds of social networks and it is postulated to come from the "rich get richer" phenomenon or a combined effect of "growth" and "preferential attachment". For examples, Newman (2001) and Yeung, Liu and Ng (2005) also got the power-law form for the productivity (or number of papers per authors) in the research collaboration networks and got the values of the exponent $n = 2.1$, 3.41 and 2.86 for the physics teaching, computer science and medicine networks, respectively. In the present network, the most active participant has 633 co-discussants while 23% of participants have no co-discussant (as all topics started by them were not replied by anyone else at all and they did not participate in other topic starters' discussion). Another 29% of the participants have just only one co-discussant. These results are comparable with the result for physics teaching networks in which 32% of the authors have no collaborator at all (Yeung Liu and Ng, 2005). Figure 4 reveals a global picture of the network concerned in which each participant is represented by a dot and links are used to join up co-discussants. Isolated dots have been intentionally moved to the circumference of the figure for the ease of identification.

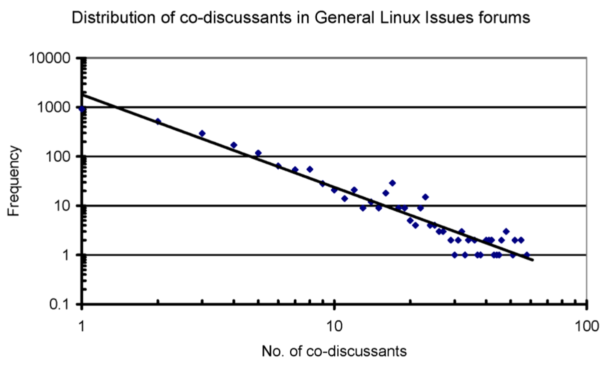

Figure 3: Frequency distribution of co-discussants

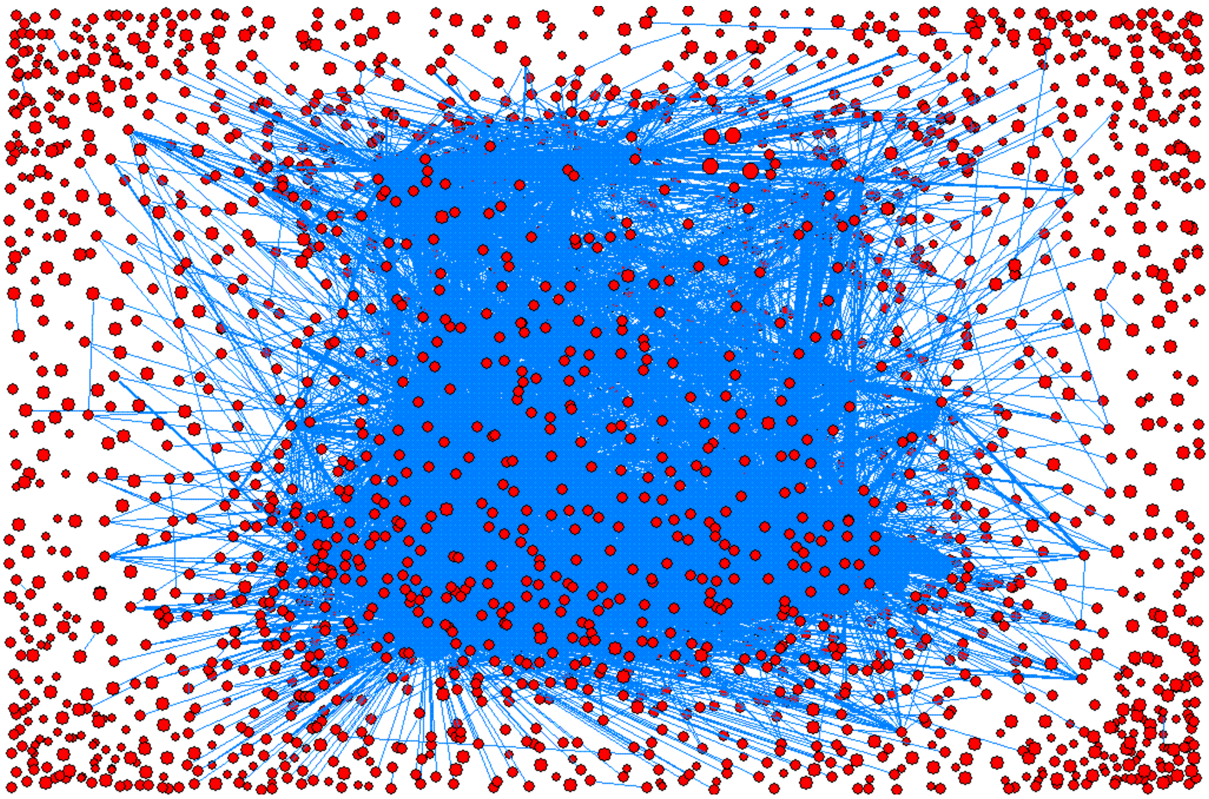

Figure 4: The collaborative learning network of 3,214 participants (denoted by dots with straight line for co-discussion linkage) in the 4 forums of the General Linux Issues area

CONCLUSIONS

The rationales and importance of studying large-size CSCL networks have been introduced and discussed. A workable framework was outlined together with a concrete example on how to analyze some online discussion forums in a chosen public website. Some new and interesting results for large-size CSCL networks were obtained. In particular, it was found that the number of replies for a given topic follows an exponential distribution, the number of views follows a log normal distribution and the number of co-discussants follows a power-law distribution, revealing that it is a kind of "scale free" network. All results deviate significantly from the Poisson distribution which is a typical characteristic of a *random network* (Albert and Barabasi, 2002).

While this short paper opens a new direction of research on CSCL networks, there are still much more work to be carried out in future. In particular, we need to develop computer programs to efficiently extract important network features from very large-size networks. We could also study the time evolution of those networks by retrieving forum data at regular time intervals (say, every 3 months). Finally, we need to study forums in many other types of websites to confirm if those network characteristics are actually universal in nature. Those macroscopic results for large-size CSCL networks will certainly help us obtain a global understanding of the sorts of interaction and sharing between learners and could potentially be applied to design and implement some small/medium size CSCL networks in a better way.

ACKNOWLEDGMENTS

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Story-Lines: A Case Study of Online Learning Using Narrative Analysis

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Abstract. Narrative analysis has both research and pedagogical advantages for use in CSCL. Narrative theory provides multidisciplinary perspectives and methods from diverse fields. Stories are a way of thinking, making meaning, and showing constructivism in action. This paper discusses the advantages of narrative analysis for interpreting online discourse; presents features, methodological challenges, and procedures; and presents some findings from a case study of online learning. Narrative analysis uses both text and online "talk" to construct a holistic view of the learning experience involving cognition, affect, and interaction.

Keywords: Narrative analysis, co-construction of knowledge, co-reflection, action research, affective domain, distance learning, wiki

STUDY PURPOSE AND DESIGN

This case study examines collaborative learning in an online action research course I facilitated in spring 2004. The two students, Ruth and Sarah (fictitious names), were graduate students in the Library and Information Science (LIS) Program, University of Hawai'i. They studied action research and applied their knowledge to an independent research project focused on their telementoring of two high school students. The pedagogical model used for the course was adapted from Gordon Wells' (1999) dialogic inquiry concept: individuals use experience, knowledge, and information to co-construct knowledge and create, use, and improve representational artifacts.

The purpose of the study was to examine how the co-construction of knowledge occurs and the effects on participant understanding of action research. Special attention was paid to the affective dimension. The data were captured mainly by computer. The online workspace used WikkiTikkiTavi, software that implements a wiki-style collaborative workspace, with added email and chat software programs dedicated to the project. Online data included: (1) email messages, (2) journal entries, (3) "wiki" pages and comments on those pages, (4) chat transcripts, and (5) server logs. The few face-to-face meetings and interviews were audio recorded and transcribed. A final questionnaire about the course was administered. The small number of students encouraged extensive and intensive discussions, often resembling coaching or mentoring. Via email, Ruth sent the instructor approximately 14,550 words and received 17,190 words from the instructor, while Sarah sent 36,990 words and received 35,730. Ruth's course activity in email, journals, wiki pages, and chats totaled 35.940 words, while Sarah's totaled 75,420.

NARRATIVE ANALYSIS OF ONLINE DISCOURSE

My assumption was that the co-construction of knowledge would be seen in the written exchanges of words that took place via email, chat sessions, journals with commentary, and wiki page postings with commentary. I first attempted to use conversation analysis and grounded theory coding to look for patterns of interaction and possible evidence of a correlation with student progress in understanding the core concepts of action research. Conversation analysis was appropriate for chat transcripts but could not be effectively applied to email exchanges, as messages were sometimes well over 1,000 words and addressed multiple topics, resembling letters more than conversations. Moreover, limiting the analysis to a concept-by-concept comparison failed to capture in depth the understandings that were most valued by the students themselves. The students were engaged in different learning processes, valued different course readings, chose to interact with the instructor differently, and produced significantly different kinds of research studies as a result. Though the coding addressed cognition, affect, and interaction, it failed to capture the emerging stories of the meaning of the experience for each student. I then turned to narrative analysis.

Stories are a way of thinking and making meaning; narrative analysis can be used "to explore the semiotic, cognitive, and sociointeractional environments in which narrative acquires salience and to which stories in turn lend structures" (Hernan, 2003: 3). Unlike most approaches in social and cultural studies, narrative analysis does not "shy away from uncertainty, complexity, and polarization" (Roe, 1998: 17). Narratives and life histories thrive because of subjectivity – they convey the fullness of thoughts and feelings and the richness of human experience. Narratives reveal concerns and vulnerabilities, help create identity and social reality, and sometimes trigger transformations. "Precisely because they are essential meaning-making structures, narratives must be preserved, not fractured, by investigators, who must respect respondents' ways of constructing meaning and analyze how it is accomplished" (Kohler Riessman, 1993: 4).

Features of Narrative Analysis

"A minimalist definition of narrative might be 'a perceived sequence of nonrandomly connected events'" (Toolan, 1988: 7). A story is represented by a plot that conveys meaning through both its narrative content and its discourse. A plot consists of sequential and *consequential* events – "the events in the story must disrupt an initial state of equilibrium that sets in motion an inversion of situation, a change of fortunes – from good to bad, from bad to good, or no such reversal of polarity, just an 'after' different from the 'before'" (Franzosi, 2004: 57). Labov (1972) posits six parts to the narrative: (1) abstract, (2) orientation, (3) complicating action, (4) evaluation, (5) result or resolution, and (6) coda. The essential part is the complicating action. The emphasis in narrative analysis is on action and agency rather than structural analysis or static variables (Franzosi, 2004). Based on a simple narrative framework consisting of character, plot, and changed narrative situation, learning narratives can be viewed as consisting of learner resources, changes in frames of reference, and resulting learning outcomes. The primary learning narrative is based on the course framework, under which other significant learning narratives are subsumed.

Methodological Advantages and Challenges

The use of narrative has both pedagogical and research advantages for CSCL (see, for example, Kupperman & Weisserman, 2000; Mor & Noss, 2004). A story can be a tool for thinking that allows students to express thoughts, feelings, and judgments regarding causes and resulting actions or effects. Change is a necessary feature of narratives. A basic textbook definition of learning (Schunk, 2004: 484) is "an enduring change in behavior or in the capacity to behave in a given fashion resulting from practice or other forms of experience." A more complex view is offered by transformative learning theory (Mezirow, 2000: 5): "[learning is] the process by which we transform our taken-for-granted frames of reference … to make them more inclusive, discriminating, open, emotionally capable of change, and reflective so that they may generate beliefs and opinions that will prove more true or justified to guide action." Four types of changes in frames of reference are the indicators of learning – elaborating frames of reference, acquiring new frames of reference, changing points of view, or changing habits of mind (Mezirow, 2000). A major benefit of the conception of learning as narrative is a greater emphasis on how students use their frames of reference to make meaning. This respects individual backgrounds and learning differences and serves as a counterbalance to the predominantly behaviorist orientation of many classrooms and educational textbooks (e.g., Schunk above). Narratives can be used to share ideas and feelings, co-construct knowledge, and build common understanding.

For CSCL researchers, narrative analysis offers features that complement other discourse analysis methods. Speech act theory uses the language act as the unit of analysis, associated with rules of use. Grounded theory (qualitatively) and content analysis (quantitatively) focus on core constructs as the building blocks or supporting elements for theory. Conversation analysis focuses on spoken or speech-like interaction patterns. Narrative analysts can use both text and talk to apprehend a holistic view of learning that focuses on change and agency. This allows analysts to perceive the construction and co-construction of knowledge at the levels of event, episode, or longer processes over time. It lends itself to longitudinal case studies that can contribute to theory building and complement experimental studies and quantitative case studies. It also has the advantage of clarity and meaningfulness in the presentation of research results, an important issue for communicating with practitioners and policymakers.

As a meaning-making tool, narratives are necessarily selective and subjective. Ruth and Sarah used course resources differently to produce their assignments, projects, and final reports. As researcher, I interpreted their discourse to determine the plots for their narratives. My stance as a full participant-observer had advantages and disadvantages. By studying my own teaching, I could use the intimate knowledge I had about the context, participants, and processes. I was highly motivated to understand how my students learned, to innovate and adapt my teaching for the online environment, and to delve into the meaning of virtual teaching through experiencing it. The disadvantages of being an insider researcher include: (1) blindness to aspects of the setting and participants that could be more easily seen by a detached observer; (2) bias that causes the researcher to take sides in conflicts of interest; (3) ethical issues of trust, possible deception, and how much can be revealed without harming others; (4) personal issues and emotional stress related to sustaining learning relationships vs. achieving research goals; and (5) power issues in the relationship between instructor/researcher and participants. I addressed these competing claims of objectivity and subjectivity through methodological and data triangulation, consulting the participants and other researchers, iteratively scrutinizing the data to confirm or disconfirm findings, and returning to the literature to ensure reasonable objectivity while benefiting from the insights that often come with empathy and commitment.

Procedures

Plots for the primary narrative and most significant sub-narrative for each student case were identified, as well as the role played by student-instructor interaction. The primary narratives were derived from the course goal: to learn about action research. In each case, the primary narrative was presented in a structure adapted from Labov: (1) *Abstract*: a brief summary of the case; (2) *Orientation*: participant background and social context; (3) *Beginnings*: learning key concepts of action research; (4) *Complicating Action*: planning and conducting research; (5) *Result*: final paper; (6) *Evaluation* (by student): final course comments; (7) *Evaluation* (by researcher): case analysis; and (8) *Coda*: epilogue to the individually and socially constructed learning narratives.

The most significant sub-narratives indicating unique student learning were identified through texts that were self-revelatory of critical moments in understanding (often labeled as "aha's"). Important sequential and consequential events, as well as learning outcomes, were selected. Relevant texts were analyzed in detail. By examining this evidence and referring to prior work on reflection and reflective practice (Boud et al., 1985; Dewey, 1997; Mezirow, 2004; Schon, 1983), a common plot structure was developed for the sub-narratives: (1) being confronted with a challenging question or situation, (2) bringing prior experience to the thinking process, (3) dealing with feelings related to the challenge, (4) reframing perspective, (5) making a leap of thinking, (6) integrating new knowledge cognitively and affectively, (7) with implications for future practice. The following section presents a summary of some of the major findings.

ACTION RESEARCH LEARNING NARRATIVES

A narrative learning model consisting of learner resources, changes in frames of reference, and learning outcomes was developed, incorporating aspects of dialogic inquiry (Wells, 1999) and transformative learning theory (Mezirow, 2000). Learners (including instructors) bring different resources and make different contributions to learning narratives – in content, rhythm of activity, and affective, cognitive, and interactional dimensions. In most settings, instructors provide the structure and goals, using their frames of reference to design and conduct activities. They use affect appropriately to facilitate learning and to build trusting relationships that encourage co-reflection and the co-construction of knowledge. Using differing personal resources, learners act, reflect, interact, and co-reflect to co-construct knowledge and to create and refine artifacts to achieve new understandings and appreciations. A change in a frame of reference signals the plot of a learning narrative. The desired learning outcomes are greater understanding and higher self-efficacy within the course framework. Self-efficacy is one of the most important tools for self-empowerment (Bandura, 1997). Perceived self-efficacy influences motivation to set and achieve goals. These intentions play an important role in learning, as recent work on intentional conceptual change demonstrates (Sinatra and Pintrich, 2003). Learning transformations do not always result in higher perceived self-efficacy. Lower perceived self-efficacy, with attendant affective discomfort, may be the impetus for a new cycle of learning in which the learner is highly motivated to change the state of affairs through intentional conceptual change.

Learner Resources

In this study, the professional culture shared by participants as experienced teachers and trained librarians provided a common set of values and concepts related to inquiry learning, learner agency and self-empowerment, information literacy skills, social responsibility, and lifelong learning. Despite the common values and assumptions, there were marked differences in learning style and experiences with reflective practice, mentoring, and online learning.

Changes in Frames of Reference

The two primary narratives of learning about action research were significantly different because of the unique sub-narratives in each student case. Ruth's most significant sub-narrative describes her process of self-discovery about the influence of learning style on her teaching and learning. The plot, derived from her final paper, consists of seven key features: (1) confronting evidence that she was biased toward visual learners; (2) reflectively examining her thoughts, feelings, and behavior as a teacher, mentor, and mentee; (3) dealing with feelings of self-doubt, frustration, and the need for self-growth instead of self-sacrifice; (4) using evidence and metaphors to understand that her view of herself as a good teacher who accommodated diverse learners was inaccurate; (5) redefining good teacher to include the importance of self-awareness, reflection, and professional development; (6) confirming that she had the personal power, wisdom, and confidence to continue learning, growing, and becoming a good teacher as she had redefined it; (7) resulting in plans for teaching to diverse learners while introducing them to new strategies to cope with a wide range of learning situations.

In the Ruth-instructor dyad, the co-construction of knowledge that supported Ruth's learning focused on the nature of action research and learning style differences. A garden metaphor was an intersubjectively meaningful conceptual artifact that grew in richness over time and provided new understandings and appreciations of the research process for the pair. The instructor's accommodation of Ruth's visual learning style was a consequential event that contributed to Ruth's reassessment of herself as a teacher. Dealing with learning style differences resulted in transformations in Ruth's and the instructor's views of themselves and each other as teachers and learners.

Sarah's most significant sub-narrative describes the building of a virtual relationship with her high school telementee, Corel. The plot, derived from her final paper, consists of: (1) being confronted with a perceived inability as a librarian to help Corel complete her senior project; (2) using her experiences as a teacher to understand Corel, transfer interpersonal strategies to the virtual setting, and analyze the communication as a researcher; (3) dealing with frustrations over her role as a librarian-telementor, fears about being unable to help Corel, and the pleasure of their exchanges of ideas, experiences, and feelings; (4) examining the data to identify her other roles in the relationship; (5) recognizing that relationship building, not coaching information literacy skills, was the achievement to be valued; (6) accepting and valuing her most important role as supportive listener; (7) resulting in recommendations for future telementoring and senior project programs.

In the Sarah-instructor dyad, the focus of the co-construction of knowledge that supported Sarah's learning was research on the telementoring project. The examination of the telementoring relationship between Sarah and Corel was a mutual research interest and in part a collaborative endeavor. The representational artifact that embodied the co-construction of meaning and knowledge about this research was Sarah's final paper.

Learning Outcomes

The course objectives were greater understanding and higher self-efficacy related to action research. Greater understanding comes through critical reflection that can lead to four learning transformations (see Mezirow above). While points of view may be changed by "trying on another's point of view, we are unable to do this with habits of mind. The most personally significant and emotionally exacting transformations involve a critique of previously unexamined premises regarding one's self" (ibid., p. 21-22).

Ruth underwent the most exacting type of transformation by critiquing "previously unexamined premises" about herself as a teacher. In her final paper, she addressed her process of self-change, its risks and vulnerabilities, and its great personal significance. She achieved a more accurate self-understanding, a more open-minded and empathetic view of her students, and a basis for more effective future action. Ruth's final comments are a concise, elegant description of both a mature understanding of one type of action research and her own personal transformation: "Action research is exactly that. It is research that 'moves.' What 'moves' in action research is the researcher's understanding of himself/herself. The understanding 'moves' from limited insight to expanded outcomes, from frustration with not being able to change others to a focus on changing what you can – yourself."

While Ruth's change was dramatic, Sarah worked steadily at incremental changes in frames of reference. Her most important learning was that she was able to build a virtual relationship with Corel. At first, she did not see a relationship developing. By analyzing the data and co-reflecting with the instructor, she identified the supportive listener role that enabled her to reach her goals "to be a caring, nurturing, compassionate teacher who valued student input and the rapport between students and teacher; who provided the opportunities for student inquiry and encouraged students to take intellectual risks." Through applying action research, Sarah became discriminating about the relationship and precise in her ability to analyze it. Sarah provided other evidence of progress. Her study evaluation was a masterful critical review that applied all the key action research concepts.

Despite the differences in the primary learning narratives and sub-narratives, both students successfully achieved the course objectives: greater understanding and higher self-efficacy related to action research, albeit different types of action research. Affect and interaction were important aspects for their success.

Benefits of Simple, Flexible Collaborative Software

I chose to use the simplest collaborative web software available to me. While it may be argued that sophisticated software (e.g., with visual features for visual learners) would have better supported learning, the results indicate that the simplicity of the software was well matched to the level of user skills. I argue that under these conditions, more sophisticated software would have imposed a high learning curve with respect to the technology and detracted from efforts to achieve the learning objectives. Software with many features increases the complexity of task completion. Combined with the social differences mentioned above, online collaborative learning can become overwhelming when users are faced with unnecessary complexity. The participants in this study relied on social capital and individual inventiveness to creatively use the software to accommodate different learning and communication styles. The fundamentals of social capital include strategies for maintaining learner motivation; relationship building based on respect, trust, sincerity, and concern; intersubjective meaning making and co-reflection; and strategies to support whole-person learning for understanding and empowerment. Flexible wiki-style software allowed participants the freedom to explore and create but also required continual effort to ensure ease of use and orderliness.

CONCLUSIONS

Three factors contributed to the choice of narrative analysis to examine online learning: (1) the narrative is a familiar form for making meaning from experience; (2) learners are unique in background and learning style; and (3) wiki-style collaborative websites are flexible and easy for even novices to use and adapt. Learning is itself a narrative focused on changes in frames of reference. Both students used narrative as a conceptual artifact to scaffold their learning – Ruth in the form of metaphors and Sarah through personal stories. They used the same learning resources in markedly different ways, taking advantage of the freedom allowed by the software to construct and co-construct knowledge, reflect, and negotiate differences. The focus on action and agency afforded by narrative analysis provided a means to apprehend and interpret these richly different learning experiences. Because of the complexities of socially constructed knowledge, classical analyses often fail to reveal significant discovery processes driving knowledge construction. Wiki-style websites provide an open record of the evolution of socially constructed knowledge. Narrative analysis offers a theoretical framework for elucidating the processes underlying that evolution. This work suggests that evaluations of online learning in which students have a significant role in creating written artifacts of their experiences can benefit from the use of narrative analysis.

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Advanced Digital Video Technologies to Support Collaborative Learning in School Education and Beyond

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Abstract. The aim of the paper is to characterize two new advanced video technology software systems developed for uses in collaborative learning (DIVER[1] and HyperVideo[2]), and how they extend the paradigms of video use in classrooms today. The rationale for and characteristics of these tools are described, and early experiences with their educational uses are characterized.

Keywords: Cognitive tools, advanced video technologies in school education, teacher education, collaborative knowledge construction

INTRODUCTION

In school-based education of today, video is normally utilized as supplement to teacher lectures, in order to enrich regular lessons and to situate or visualize knowledge for a better understanding of a topic at hand. Empirical findings concerning the effectiveness of such video supported learning consistently show that comprehension and transfer of knowledge can be facilitated by dynamic (audio)visual formats in many domains - and that this is especially true for interactive presentations (Cognition and Technology Group at Vanderbilt, 1997; Park & Hopkins, 1993).

Introducing video into school-based education in the future could consist of utilizing *new* advanced digital video technologies as cognitive tools that broaden the spectrum of the existing video use paradigms: Advanced digital video has brought about new conventions of filmic expression in many areas—whether in the arts, at home or in the workplace. In many workplaces, advanced digital video technology is not only a means of communication via video conference, but is also used for collaborative video analyses, e.g. in the area of professional sports, teacher education or in the life sciences. Such advanced technologies may include tools for the selection of single video scenes from existing video information and for the direct integration of video scenes with e-communication facilities. Thus, we are confronted with a situation where we need to establish new components of visual literacy and digital literacy that relate to such work scenarios. Literacy concepts cannot be restricted to static and text-based media anymore, but have to integrate the understanding, analysis and active use of non-linear and audiovisual media as well including the use of digital video technology (Pea, 1991; Pea & Gomez, 1992).

To this end, advanced digital video technologies may become part of our educational systems and the question is then: How can such technologies (and new paradigms, respectively) be implemented in schools and in educational and learning processes broadly? How does the use of digital video technology interact with the cognitive concepts and prerequisites of students and teachers? Our two groups—in Germany and the United States—have been working in parallel on exemplars of a paradigm that is already a part of our everyday lives, but which has been minimally appropriated yet in K-12 education. In the present contribution, we will focus on these two advanced educational digital video systems that were explicitly developed on the basis of cognitive and socio-cognitive psychological and pedagogical considerations.

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[1] DIVER™, WebDIVER™, Dive™ and "Guided Noticing"™ are trademarks of Stanford University for DIVER software and affiliated services with patents pending. The DIVER project work has been supported by grants from the National Science Foundation (#0216334, #0234456, #0326497) and the Hewlett Foundation. The DIVER team contributing to these efforts includes Roy Pea (Director), Michael Mills, Joe Rosen, Kenneth Dauber, and graduate students Robb Lindgren, Paula Wellings, Sarah Lewis and Lori Takeuchi.

[2] The HyperVideo system was developed at the Computer Graphics Center in Darmstadt, Germany in cooperation with the Knowledge Media Reasearch Center in Tuebingen, Germany.

DIGITAL VIDEO TECHNOLOGIES AND GROUP KNOWLEDGE PROCESSES

Learning to observe - Learning to analyze: The DIVER system was developed by the Stanford Center for Innovations in Learning. DIVER is based on the notion of a user “diving” into videos, i.e., creating new points of view onto a source video and commenting on these by writing short text passages or codes (Pea, Mills, Rosen, Dauber & Effelsberg, 2004). DIVER makes it possible to readily create an infinite variety of new digital video clips from any video record. A user of DIVER software "dives" into a video record by controlling—with a mouse, joystick, or other input device—a virtual camera that can zoom and pan through space and time within an overview window of the source video. The virtual camera can take a snapshot of a still image clip, or dynamically record a video “path” through the video to create a dive™ (which we also call a DIVER worksheet, see figure 1 below). A dive is made up of a collection of re-orderable “panels”, each of which contains a small key video frame that represents a clip, and a text field that can contain an annotation, code, or other interpretation. Diving on video performs an important action for establishing common ground that is characterized as “guided noticing” (Pea, in press). The use of the virtual camera for the framing of a focus within a complex and dynamic visual array directs the viewer’s attention to notice what it is that is thus circumscribed, and the point-of-view authoring thus guides the viewer to that noticing act. In this way, DIVER can be used as a tool to promote the development of “professional vision” in learning within disciplinary domains (Goodwin, 1994).

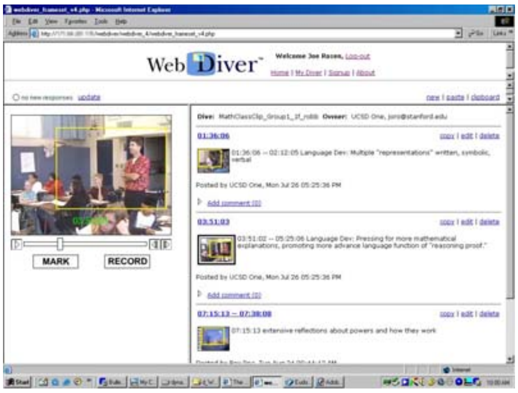

Figure 1: DIVER worksheet

Originally, DIVER’s primary focus was for supporting research activities in the learning sciences (such as interaction analysis: Jordan & Henderson, 1995), and in teacher education, where video analyses play a major role for understanding one’s own behavior and reflecting on it in relation to the behavior of others. DIVER has also been designed to enable the active exploration of panoramic video data—where one or more digital video cameras and associated mirrors are used to capture 360-degree horizontal imagery. In this case as well, the user may select visual information by virtually ‘pointing to it’ in the much larger spatio-temporal data structure of the video, for the purposes of collaborative reflection and analysis. The final product then is a collection of separate short video segments with annotations that represent the user’s point of view on the video.

There are two different ways users work with video using the DIVER approach. In the first, after creating a dive using the desktop DIVER application, the user can upload it onto WebDIVER, a website for interactive browsing, searching, and display of video clips and collaborative commentary on dives. In an alternative version of the WebDIVER system, one can dive on streaming video files that are made accessible through a web server over the Internet, without either requiring the downloading of a DIVER desktop application or the media files upon which the user dives. Using WebDIVER in either of these ways, a dive can be shared over the Internet among teachers, student-to-student, teacher-to-students, or in other scenarios with colleagues and become the focus of knowledge building, argumentative, tutorial, assessment or general communicative exchanges.

On a generic level the system might be described as a cognitive tool that enables “pointing to video” and thus helping to develop skills of observation and noticing details and enhancing the probability that in collaborative processes, the focus of attention and negotiating of meaning between participants in a conversation will build upon a common ground. With DIVER it becomes obvious that advanced technology may not only amplify existing kinds of activities and communication, but that it might augment our spectrum of activities and initiate entirely new forms of learning (Pea, 1985).

The DIVER system distinctively enables what its creators call “point of view” authoring of tours of existing video materials in a way that supports sharing, collaboration, and knowledge building around a common ground of reference (Pea, in press; also see Goldman-Segal, 1998 and Stevens et al., 2002 for related prior work). This form of communication with video is important for tapping the powerful potentials of video-enhanced learning in the classroom.

Learning to integrate text and video - learning to design: The web-based HyperVideo system for collaborative learning was developed at the Computer Graphics Center/Darmstadt in cooperation with the Knowledge Media Research Center/Tübingen. It is based on the idea of "annotating movies," i.e. selecting video segments from a source video and having spatio-temporal hyperlinks added to video: Users of the HyperVideo system can create dynamic sensitive regions within video materials and add multiple links to these sensitive regions. The links can consist of data files uploaded from a local computer, as well as URLs. The links can then be discussed by means of an integrated e-communication tool. Thus, users can include their own annotations and knowledge in a video and share them with others in a group or community. The overall design approach encompasses several steps: (1) information is mainly presented by video, (2) knowledge can be collaboratively expanded by means of both dynamic links and written e-communication, and (3) the process of knowledge building is reflected in a resulting hypervideo structure we denote as a 'dynamic information space' of a collaborating group (*DIS*, Chambel, Zahn & Finke, 2004).The system is based on client/server architecture. The web-based graphical user interface (GUI) is shown in figure 2. A special video player (upper left part, see below) displays the spatio-temporal hyperlinks (white rectangles) within the video frame and offers functionalities in order to create new video annotations. The separated navigation space below the video player helps the users to navigate within the DIS. On the right side of the screen, additional information and the users' discussions/comments are displayed. Newly created video annotations are immediately transferred from the client to the server in order to be instantly shareable by the community.

On a generic level, the HyperVideo system is as a cognitive tool enabling the linking of video information thus helping users to learn to establish non-linear information structures and to focus their attention and discussion in collaborative learning on associated concepts or related external representations of knowledge (e.g., a visible object and a text, or visible object and a formula). Such uses have been discussed in the context of performing collaborative hypervideo design projects (Chambel, Zahn & Finke, 2004). A respective program and the technology were evaluated and further developed during three psychology courses at the University of Muenster/Germany that were planned according to an instructional program based on courses of hypertext writing, originally developed by Stahl and Bromme (2004).

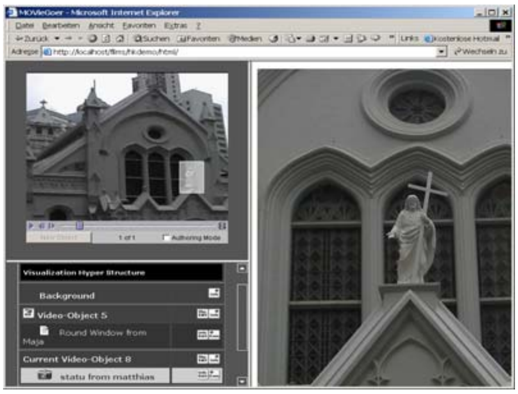

Figure 2: Graphical user interface (GUI) of HyperVideo

ADVANCED DIGITAL VIDEO SYSTEMS AS 'RHETORICAL PROBLEM SPACES' IN COLLABORATIVE SITUATIONS

Stahl and Bromme (2004) - applying Bereiter & Scardamalias (1987) model of knowledge transformation to the process of learning by hypertext design - assume that the peculiarities of hypertext may influence the process of learning in very specific ways: 1) Hypertexts are non-linear media, so hypertext design processes do not only include linear writing processes, but also the selection and creation of small "nodes" and the representation of concept relations by links and an overall structure (integration). Also multiple ways of "reading" the hypertext must be considered (e.g., multiple audience perspectives). This should lead learners to a very deep elaboration of content. 2) Hypertext design problems (due to their complex nature) are solved in cooperation and collaboration with others, so the production process has to be coordinated in a group. This should lead to collaborative knowledge building and knowledge exchange. 3) Hypertext design has just begun to emerge, so that even among professionals different 'metaphors' (= genre knowledge and mental models of the medium) can be applied. To be able to work and learn, students have to consciously develop and negotiate upon a joint idea of 'what a hypertext is' as a first step of their coordinated work. Finding an appropriate metaphor should lead to developing discourse knowledge, on the one hand, and further joint elaborations of the content, on the other hand. These assumptions are also substantiated by empirical results: The reflection of different audience perspectives has been found superior to not doing so. The thorough evaluation of links representing semantic relations between nodes has been found to lead to a deeper elaboration than not using such activities. And finally, a space metaphor showed to guide knowledge transformation processes better than a book metaphor of hypertext (Stahl & Bromme, 2004).

Similar assumptions can be made for hypervideo design processes, too. As was described in the previous section, we view advanced digital video technologies as cognitive tools according to a perspective of distributed intelligence (Pea 1993, 2004). Merging this view with the works on hypertext design fostering knowledge transformation processes (Stahl & Bromme, 2004), we generally perceive advanced digital video technologies as *establishing new rhetorical problem spaces with their own rhetorical rules*. These rhetorical problem spaces can well be understood in the sense of Bereiter and Scardamalia (1987) who assumed two problem spaces as important for text writing: the content problem space and the rhetoric problem space.

However, because in the present context we have to deal with digital video, the rhetoric problem spaces in hypervideo design tasks are (audio-)visual ones instead of being merely based on text. Consequently, the rhetorical rules of our new rhetorical problem spaces relate mainly to visual and filmic codes (such as mise en scène and montage), rather than relating solely to text. And hypervideo design as a rhetoric problem, finally, includes relating to different text genres, to the visual codes and styles of pictures/graphical displays *and* to the dynamic visual codes of film and animation. This, in turn, constitutes the educational value of such tasks.

COLLABORATIVE ACTIVITIES INVOLVING ADVANCED VIDEO TECHNOLOGIES

We are now exploring in pilot studies a variety of ways that collaboration among school students can be advanced in learning using advanced video technologies such as the two systems we have described. In WebDIVER, learners can collaboratively analyze video records from archival sources (e.g. science videos), or from video they have themselves collected (e.g. of fieldtrips, art museums, classrooms). In the HyperVideo system, learners and teachers can collaboratively create hypervideo documents (e.g. in university courses, as mentioned above) on the basis of existing or of self-shot videos. In both the Stanford and German software systems, collaborative video work can take place either face to face in a computer-intensive school setting or after-school club, or over computer networks, involving distant locations, either synchronously or asynchronously. These are the main features that distinguish the two systems from related works. Moreover, in both systems, learning scientists can also collaboratively engage with video, to interpret and analyze educational interactions or other behaviors of interest to their studies.

In preliminary work with the WebDIVER collaborative video analysis framework, we have found utility in the following scenarios: (1) pre-service secondary teachers in Stanford's school of education, creating dives of ten-minute unedited videorecordings of their own teaching, which they analyze with respect to the rubrics which their faculty mentors use to evaluate their work; (2) learning science doctoral students collaboratively analyzing teaching videorecords according to different disciplinary perspectives (anthropology, linguistics, sociology, developmental psychology, educational psychology, cognitive science) and then working to combine them to deepen the quality of interaction analyses; (3) distributed researchers working to analyze video data from user studies, in this case, of preschool children interacting with a touch-screen video-based storytelling system we call KiddieDIVER, and providing a collective set of recommendations via a dive on these data that was shared with the software engineer over the web for review and implementations of software improvements based on insights from the collaborative video analysis activity; (4) faculty use in preparing dives on videos of secondary educational practices that are used in lectures to exemplify and explore theoretical concepts from the research literature used in their courses (e.g., cognitive apprenticeship, scaffolding, academic language); and (5) a film studies professor working with his students to compare several different film versions of the Shakespeare Play Henry V.

In each of these scenarios, we are finding that collaborative diving requires working in new rhetorical spaces, in cooperation and coordination with others. We make several points on the last scenario to exemplify the transformative nature of such activities with respect to common pedagogical methods: Film students spend considerable time studying major filmmakers, film genres, the grammar of cinematography (Metz, 1974), as well as narrative techniques and the animated special effects that have defined recent film developments. DIVER provides a new tool for the faculty member and film student to develop the web of perceptive knowledge that ties together the history of films, filmmakers, film methods and techniques and film criticism. In a film studies course now underway using DIVER at Stanford, graduate students in film are studying the relationship between the actor and the written work. For example, students are looking at two clips, the 1989 film adaptation of Henry V directed and played by Kenneth Branagh, and the 1944 film version of the same

Shakespeare play directed and played by Laurence Olivier. The same scene and words will be analyzed: Henry V's "Crispin's Day" speech. Previously the film studies professor provided a related assignment to students—describing in an essay what was different about each actor's interpretation—but by having them write about the movie scenes from memory. With WebDIVER, film students are able to point to specific space-time regions of the film in real-time examples from each movie, and to justify their analysis with video-based argumentation using the scenes from the movies being compared. This exercise takes place outside of the classroom, as a homework assignment. Each student is given their own protected workspace, and they access the films and the WebDIVER analysis tool on-line via a web browser. Students will then present their analysis in class, also using WebDIVER. The students will have a chance to comment on each other's work, both orally in class and again later on-line by adding messages and comments to the web-based Dive worksheets. Although this same assignment has been used in film class before, this will be the first time a) students will be able to point directly to the scenes they're analyzing and referencing; and b) an informal learning discussion (via web page collaborative commentary) will continue outside of the classroom presentations. In WebDIVER, students can also literally navigate the movie by way of the actor's/script's utterances (i.e. click on an utterance and go directly to the corresponding scene in the movie). The utterances also scroll along with the movie. The professor anticipates a nuance and depth to analysis that he has not experienced using his previous approach to instruction and assessment.

Prior studies involving the HyperVideo system include an experimental test of how users (N= 74) learn with different design versions of a hypervideo in the domain of biology (Zahn, Barquero & Schwan, 2004) and a comparison of how (and where) authors with different prior knowledge would suggest placing hyperlinks in biology videos (Zahn, Schwan & Barquero, 2002). The results of this latter study revealed that authors of different knowledge backgrounds (content-experts, media-experts and novices) developed similar ideas of a hypervideo structure, which were mainly based on formal features of the source video (such as, for example, terms included in the audio track). Results also showed that the linking decisions of expert-authors were quite congruent with those of novice users, indicating that even users with low prior knowledge were capable to make meaningful linking decisions.

Our prior works provide the basis for applying hypervideo design tasks at school. As a starting point, hypervideo design will be applied in German secondary schools to support media education in German native language lessons ("Deutschunterricht"). The topic will be TV-advertising. We plan to study the collaborative analysis of TV-ads based on the DIVER system and the collaborative hyperlinking of TV-ads based on the HyperVideo system. Altogether, we will conduct two large experiments in a learning lab. Our interest is to investigate the interactions of DIVER and HyperVideo as two generic types of digital video technology with a) individual cognition (i.e. mental models of "hypervideo" in learners) and b) teacher's instructions (i.e. the support of group discussion by teachers) and the influences of these interactions on group knowledge processes. This future-orientation leads us to the last section of this paper.

CONCLUSION

In writing about modern music, writing, art and science, Umberto Eco (1989) notes that "'open' works, insofar as they are in movement, are characterized by the invitation to make the work together with the author and that (2) on a wider level (as a subgenus in the species 'work in movement') there exist works, which though organically completed, are 'open' to a continuous generation of internal relations that the addressee must uncover and select in his act of perceiving the totality of incoming stimuli." To the extent that DIVER and HyperVideo use can make video and movies and other rich media 'open' to HyperVideo linking and to Diving—interpretation and extensible use with guided noticing, DIVER path movie-making making and annotation—there is without question an active role for the reader, who becomes an author in bringing the work of the video or other medium to a more completed state in his or her interpretations of it. DIVER also provides a tool for evidence-based argumentation, in which one uses what one notices in the medium to make a case around it, and thus extends the work in significant ways with the act of authoring the dive. For the constructivist educator or more generally for those who want a more active voice in media uses for communication and knowledge production, these two systems exemplify a video use paradigm for education that moves away from today's broadcast-centric and asymmetric uses of video to the communicative empowerment of the video user, who can easily craft point-of-view movies within movies with commentaries and hyperlinks to share with others. We view this fundamental shift from consumption to authorship of video points-of-view as a vital transformation in the use of the video medium for advancing learning and education.

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Usability as an Interactional Resource: Deictic Management of Scene Formulation

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Abstract. In this paper, we describe how embodied action, in the form of pointing and other gestures, and personal and spatial indexicals are used to constitute participation frameworks and work sites in an instructional surgery. As a site for both learning and work, the operating room afforded us the opportunity to examine how usability, which is a critical design consideration, can be used as a resource for learning in interaction. In our detailed analysis of the interaction among participants (both co-present and projected) we sought to describe a particular case of how usability was achieved as a relevant consideration for surgical education in the operating room. In doing so, we demonstrate a set of members' methods by which actors establish and provide for the relevance of the projected needs of projected users as part of developing an understanding of their current activity.

Keywords: Personal deictics, spatial deictics, embodied action, pointing, gesture, interaction, collaborative instruction

INTRODUCTION

In certain kinds of vascular surgeries, certain structures called arteriovenous (AV) fistulas are assembled and/or repaired to make it easier for the patient to receive subsequent treatments, such as kidney dialysis. In teaching surgeries, these structures and the uses to which they will be put can become resources for the attending surgeon, resources that are used in the instruction of the resident who is participating in the surgery. Residents who participate in such vascular surgeries are expected to know how such surgeries are performed as well as the reasons for performing such surgeries in the first place. .

Surgeries that are designed to create or repair AV fistulas are distinct from other kinds of surgeries in that the structures that are built in these surgeries have a particular use and are built to be usable by other practitioners in other kinds of treatment settings. Thus, one of the important features of such surgeries is that the usability of the structures so built is of particular concern to the ongoing conduct of the surgical operation. To understand what must be done to create or repair an AV fistula, residents need to understand the anatomical and procedural aspects of the surgery as well as the use to which the fistula will be put. In part, there is a design element that is deeply relevant to the way these surgeries are performed and thus is a matter of practical and instructional importance for attending surgeons in the conduct of AV fistula surgeries. This design element can be described in terms of the usability of the surgically created structure for subsequent users. In the surgery we investigate, the subsequent user is the dialysis nurse.

One important feature of this kind of design work is that it is oriented toward coordinating work being done in the present with work that will take place in other settings and in other times and will involve other workers. The question that concerns us here is how are the projected needs of these other workers made visible in the present or, stated otherwise, how is usability made relevant within concrete practical activity of the ongoing surgery?

Research in CSCL is centrally concerned with learning in settings of joint activity. Joint activity, however, is often directed toward supporting other projected activities in the future; all design work has this character. The projected end user may or may not be a participant in the current activity. The question which concerns us in this paper is how are the needs of the projected user made relevant and visible within situated conversation or, in different terminology, how is usability accomplished as an interactional matter?

DATA

The data presented here comes from a corpus of video-based materials compiled in operating rooms at a teaching hospital affiliated with a medical school with a surgical residency program. This corpus was developed as part of the Deixis Project, a multi-disciplinary undertaking designed to explore how instruction is produced in the context of consequential, joint activity. The three fragments of interest occurred in a surgery undertaken to repair an arteriovenous (AV) fistula. Patients in hemodialysis clinics receive intravenous (IV) taps as a routine part of their ongoing treatment. AV fistulas are created to provide a convenient place for vascular access. The fistula is created by shunting blood from a large artery in the patient's arm or leg into an adjacent vein located near the skin. This has the effect of dramatically increasing both the blood volume and blood pressure in the vein. Over a period of time the vein adapts to this change in volume and pressure by expanding in both diameter and length, a process vascular surgeons refer to as "maturing." The swollen section of the superficial vein then becomes the access point for the dialysis nurse. In the case under study here, the patient had previously undergone surgery to create an AV fistula, but the vein had failed to mature following surgery. The surgery which was observed and described here, therefore, was undertaken to repair a defect created in the first surgery.

The participants in the three excerpts to be described here are Attending, an experienced vascular surgeon with ultimate responsibility for the safe outcome of the surgery being performed and Resident, an advanced surgeon-in-training enrolled in a surgical residency program. The surgery in this case is being largely done by the resident with the attending supervising and assisting.

Technically a fistula refers to a passage or opening between two organs or structures. In this it would presumably refer to the passage created between the (something) artery and the cephalic vein. Participants use the term *fistula*, however, more loosely to refer to the structure produced by the creation of the passage between the two vessels, that is to the matured segment of vein. The thing referred to as the fistula, therefore, becomes what Star and Griesemer (1989) described as a "boundary object" bringing together the work of the vascular surgeons and the work of the nurses in the dialysis clinic.[1]

We examine one surgery in which the attending and the resident connect their work to the future work of other health care workers, specifically the work of the nurses in the dialysis clinic. This occurs at the beginning of the operation prior to making the first incision. The attending is questioning the resident about the goals and strategy of the surgery.

ANALYSIS

An AV fistula re-routes blood flow from a peripheral artery directly into a superficial vein, causing the vein to, overtime, grow larger and become a more serviceable access site for the dialysis nurse. The task of designing and fabricating such a site causes the participants to, in the words of Goodwin (2003), invoke and deal with the simultaneous relevance of multiple phenomenal scenes" ----the access site as it appears at the moment and the access site as it must appear at the time of use. Their design work is undertaken to accommodate the needs of a member not currently present (the dialysis nurse).

Personal Deictics

The exchange between the resident and the attending involves the use of a question sequence common in classroom recitation. A question is asked the answer to which is already known by the interrogator, silence in the place where a student response would be relevant, the teacher re-formulates, etc. The question "What's missing?" is difficult because the universe of possible answers is so unbounded.

```
1    A:      So (.) this cephalic vei::n has a conspicuous
2            pulse in it (.) but what's missing
3            (4.0)
4    R:      I::z u::hb
5            (2.8)
6    R:      ⌈What's missing
```

[1] Many examples of such "boundary objects" can be seen in modern medical practice. Consider the practices of coordination employed by radiologists, surgeons, and pathologists in performing a simple breast biopsy. Prior to surgery, radiographic images are produced which demarcate the regions of tissue in question. A barbed needle is sometimes inserted by the radiologist to provide guidance to the surgeon in locating and defining this region. When the sample of tissue is excised, the surgeon may attach sutures to the specimen to display to the pathologist the orientation of the excised tissue with the patient's body. Is is only this mass of non-descript tissue that makes the tortuous journey across the boundaries of these different communities of practice.

In response to R's difficulties putting forward an adequate response, A initiates an alternative organization of inquiry. This new organization of inquiry serves to indicate that R's response is locally inadequate and, in its organization, introduces an alternative organization of relevancies by invoking a non-present but consequentially relevant actor for consideration, i.e., the dialysis nurse:

7 A: ⌊Lets lets lets lets lets lets just say you're
8 the dialysis nurse
9 R: Right=
10 A: Okay (1.0) and you wanna (.) stick a needle in
11 this
12 R: Mm mhm=
13 A: =Okay (2.0) Where↑ (.) are you gonna put that
14 needle

Let's examine the participant deictics in these two extended utterances from A. Note the shift from the "you're the dialysis nurse" (second person, temporally and physically present) to "where are <u>you</u>" (second person projected temporally and spatially to the dialysis clinic at some point in the future).

15 R: Well you know where the vein is but you don't
16 know where the artery i::s

A's question calls for R to answer as a dialysis nurse faced with the task of cannulating this patient, not in a projected state, but with the patient's arm in its current state. R's response is interesting in light of it's use of participant deictics. We see two parallel uses of the second-person personal pronoun *you*, but in neither case does it work as a conventional second-person pronoun. (If the binding was the speaker's interlocutor, the utterance would border on insubordinate.) 'You' can be used colloquially as an indefinite, third-person pronoun and that appears to be what is happening here. (Note that the third-person pro-term 'one' can be substituted syntactically for 'you' in both places.)

17 A: We- we- we're actually don't even ⌈care about
18 R: ⌊kxhmm
19 A: the artery .hhh I mean (.) we- (2.0) we've got
20 this got this cephalic vein
21 R: Mm mhm

A produces an assessment of R's response in lines 17, 19 and 20. The organization of this assessment suggests that R's response is being assessed in anatomical terms and thus invokes their shared participatory framework as surgeons in the scene.

22 A: Now think about it now .hhh (.) and you're the
23 dialysis nurse and over the next (.) <u>five</u> <u>years</u>
24 you're gonna be putting needles in this thing
25 R: Mm mhm=

However, to provide R with the warrant for A's assessment, A redeploys the use of the dialysis nurse, this time reconstituting the nurse's projected action, i.e., "you wanna stick a needle in this" (line 10), as an expectably ongoing and repeatable set of actions that are projected into the future, i.e., "over the next (.) <u>five years</u> you're gonna be putting needles in this thing" (lines 23 and 24). This escalation to a projected future history of repeated actions serves to emphasize the consequentiality of the current surgical procedure and thereby emphasize the urgency that R display a proper understanding of the purpose of this surgery.

26 A: =Okay so we want it to mature, we know the
27 cephalic vein goes from <u>here</u>↑ (1.2) to here.
28 ⌈So fr'm here all the way up to here (.) oka:y↑
29 R: ⌊Mm mhm
30 A: ⌈So
31 R: ⌊Right
32 (2.0)
33 A: What are we missing
34 R: The in between
35 A: Yeah we're missing the in between right (.)

```
36          exactly
37          (1.0)
38   A:     We're missing this ↑who::le leng⌈th here okay so
39   R:                                     ⌊Mm mhm
40   A:     .hhh sump'n is wro::ng
```

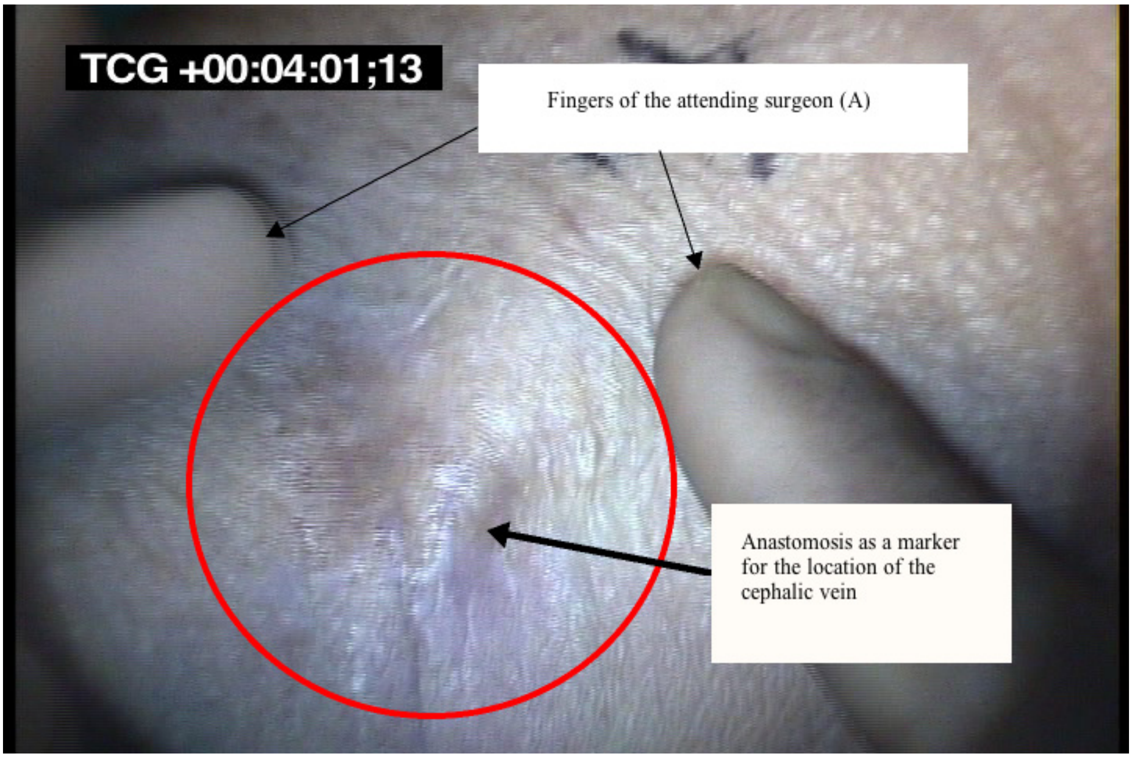
Lines 26 and 27 mark a shift from producing an explanatory scaffold by animating the dialysis nurse to a return to the student-teacher organization of interaction. The tokens "Okay so" in line 26 constitute the transition from consideration of the expected future history of how this procedure's outcome will be used to current consideration of the surgical scene. This implicitly re-invokes the "known-answer" queries that had been addressed to the resident earlier and to which the resident had not yet produced an adequate response. In order to adequately describe how this last section of the transcripted interaction allows the resident's response at line 34 to be treated as an adequate response, we must consider, in addition to the personal deictics, the spatial deictics deployed by the participants. It is only with respect to the actual surgical site and the anatomical structures constituted through spatial deictics that it is possible to recover how the resident's response can be seen as adequate.

Spatial Deictics

The previous discussion focuses on how the attending surgeon and the resident orient to each other in the production of a response to the attending surgeon's query. However, there is another set of resources of which A and R both make use and which constitute the proper domain of their collaborative work, the patient's arm. As we will see, the attending surgeon makes use of the patient's arm in ways that constitute it as three different structures of reference. The first is the patient's arm in it's current state. The second is the patient's arm as it should have become as a result of the prior surgery and the third is the patient's arm as it will become upon successful completion of the current surgery. The resources represented by the patient's arm provide points of reference in terms of the surgery to be performed, the cephalic vein, and the stenosis causing the diminished blood flow from the anastomosis to the cephalic vein. These are essentially locations and structures located in space to which the participants refer as they proceed to understand the circumstances of the surgery.

In order to produce the attending surgeon's initial query at lines 1 and 2, and an adequate response to that query, both the attending and the resident make use of the patient's arm as a semiotic and referential resource to instantiate the patient's arm as 1) the site of what should have been achieved in a prior surgery, 2) the current pre-operative site of inspection, instruction and surgery, and 3) as the post-operative arm they expect to achieve at some point in the future after the successful completion of the surgery. Constituting the observed pre-operative site as the post-operative arm made it relevant and possible for the participants to invoke the absent actor, i.e., the dialysis nurse, who at some point in the future will make use of the matured vein that is the expected result of the surgery that is yet to be performed. Likewise, referring to the dialysis nurse was part of the way that the attending could constitute the current pre-operative site as the post-operative arm it was to become. By orienting to the arm, through gesture and talk, in ways that project what that arm will become for the dialysis nurse at some point in the future, the surgeons invoke a sense of the arm's expected and projected future usability as a resource for performing dialysis. In other words, the attending surgeon's work is to demonstrate through his instructional actions the usability requirements that inform their current surgical work by "showing" how the arm will be used in the future.

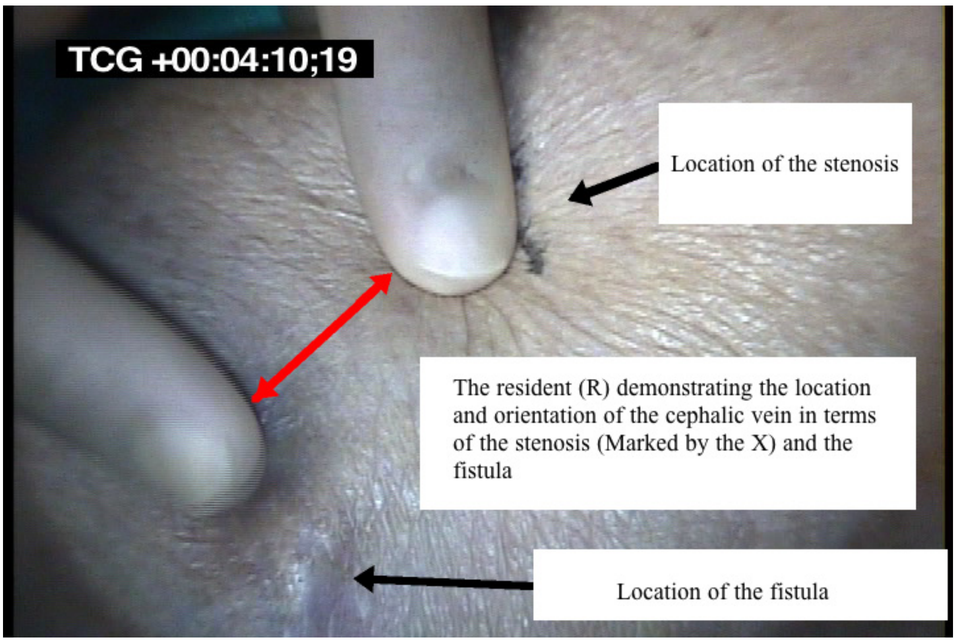
Typically, reference to spatial referents involves the use of spatial indexicals like 'here' and 'there' as well as pointing and other locative gestures. "A central locus for the act of pointing is a situation that contains at least two participants, one of whom is attempting to establish a particular space as a shared focus for the organization of cognition and action" (Goodwin 2003b, p. 219). This interaction is precisely such a circumstance. In this circumstance, talk and gesture are both deployed effectively and in a mutually informing manner to establish both the current condition of the patient's arm and it's projected post-operative condition as the work site for a different kind of activity. The pointing and deictic work done by both the attending and the resident as they discuss the site serves to constitute the patient's arm as 1) the site of what should have been achieved in a prior surgery, 2) the current pre-operative site of inspection, instruction and surgery, and 3) as the post-operative arm they expect to achieve at some point in the future after the successful completion of the surgery.




```
1    A:      So (.) this cephalic vei::n has a conspicuous
2            pulse in it (.) but what's missing
```

At this point, A is pointing to and thereby identifying an anatomical structure of particular relevance to the current surgery by pointing to its location on the patient's arm. The actual vein is not immediately observable, but there are sufficient indicators (the skin discoloration, the raised skin, etc.) to provide evidence to inferentially identify the vein and its location where it was initially joined to an artery in a prior surgery.

During the four second silence (line 3), the resident moves his hand into a position that permits him to point to the location identified by the attending surgeon. As the resident starts to produce a response in line 4, he brings his left hand into position to point to the locatin of the stenosis (the narrowing in the vein that produces blocks the flow of blood) on the patient marked with an X, as shown below. In performing this action, the resident demonstrated the location and orientation of the cephalic vein in terms of the stenosis (marked by the X) and and the fistula.

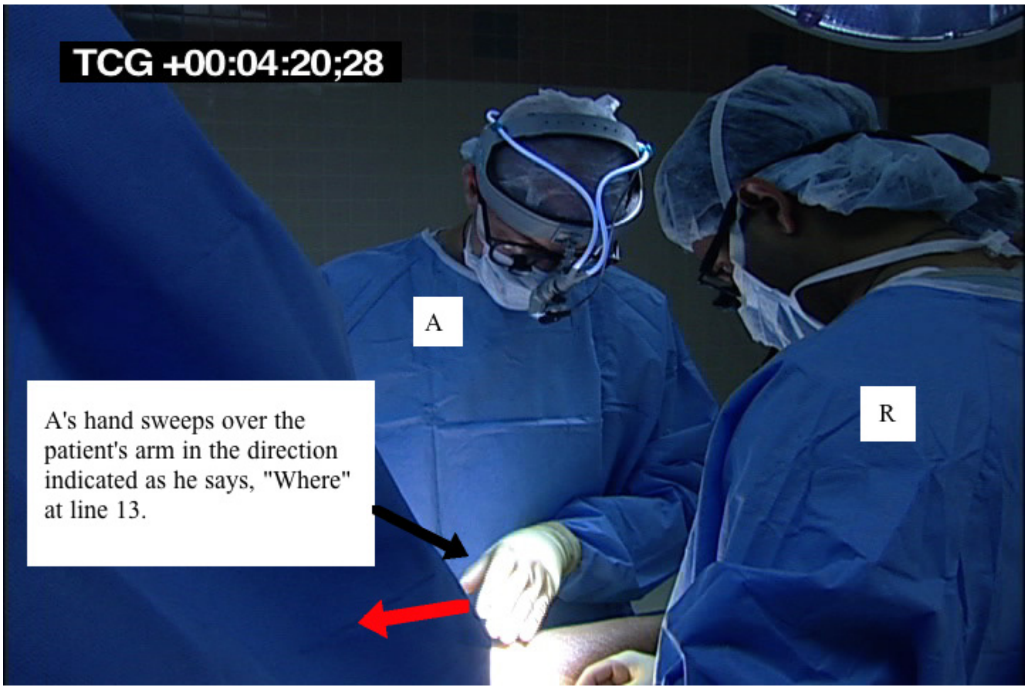


```
3           (4.0)
4    R:     I::z u::hb
5           (2.8)
6    R:     ⌈What's missing
```

R's hesitations and utterances in lines 3 through 6 are coupled with his pointing work, shown above. not having been able to produce an adequate response. The pointing work seems designed to demonstrate that he is working to understand the question as a way of responding to it. When he cannot describe for A "what's missing", R withdraws his hands. The act of withdrawal actually embodies not only R's problem producing an answer but also serves to indicate to A that R not only has not but cannot answer the question as posed. With the removal of his hands, R demonstrates in an embodied way that he is unable to respond adequately to the query as produced. This makes relevant the possibility that an alternative organization of inquiry might provide R with the resources needed to identify "what's missing".

```
7    A:     ⌊Lets lets lets lets lets lets just say you're
8           the dialysis nurse
```

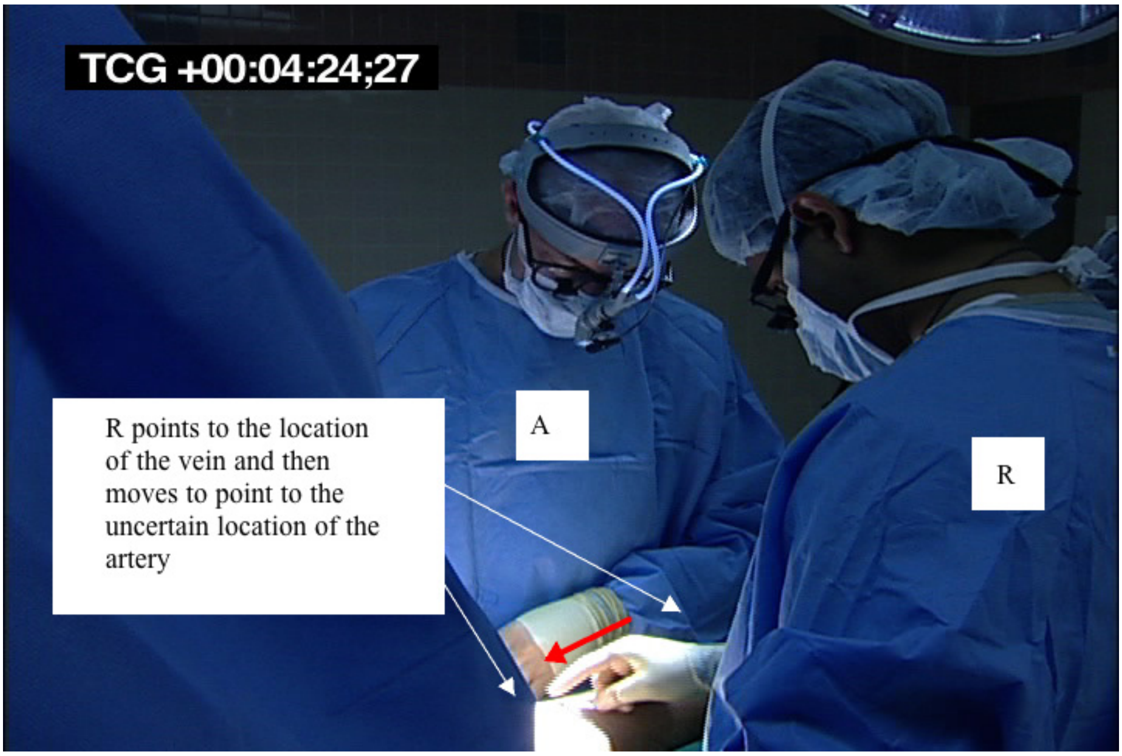
A initiates an alternate organization of inquiry in lines 7 and 8. This utterance is produced as A pats R's right hand (which, up to that point, had still maintained its pointing shape) and further removes it from the observable area of investigation. This action seems to 'wipe the slate clean', allowing A to reconstitute the worksite itself, i.e. the patient's arm, as a locus of alternative inquiry, thereby removing any vestige of the prior query's implicit organization of the features of the patient's arm. With his gesture work and by invoking the absent dialysis nurse, A's deictic work is designed to transform the patient's observed pre-operative arm into what it will become a few weeks after the completion of the current surgery as a site for dialysis.




```
9    R:     Right=
10   A:     Okay (1.0) and you wanna (.) stick a needle in
11          this
12   R:     Mm mhm=
13   A:     =Okay (2.0) Where↑ (.) are you gonna put that
14          needle
```

Having gesturally established the relevance of an alternative perspective on the arm, A then proceeds to build an inquiry at lines 13 and 14 above based on what might be called the arm in its expected future state. The query itself is sensible only under the assumption that R has animated the dialysis nurse as a participant in the ongoing interaction at A's prompting.

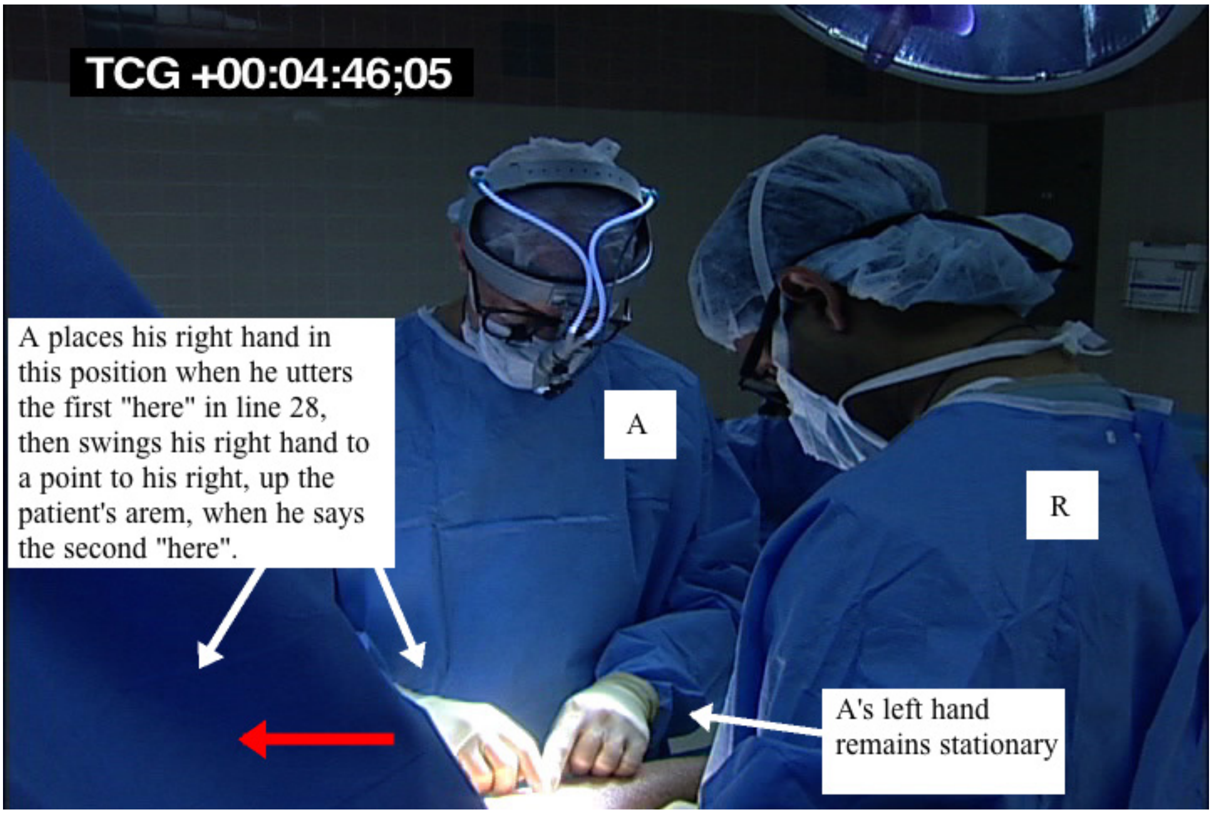
Any answer to the the query in line 13 would be treated as the answer provided by a dialysis nurse who would see the post-operative arm and the matured vein as the site of his work. By asking R to animate this persona, A not only makes it possible for R to view the patient's arm in terms of an alternative set of relevancies, but also makes it possible for R speak *as the dialysis nurse* to indicate what both *will be* of relevance in the future and what is currently relevant for the surgery. The actual response in lines 15 and 16 below are ambiguous at best.




```
15   R:      Well you know where the vein is but you don't
16           know where the artery i::s
```

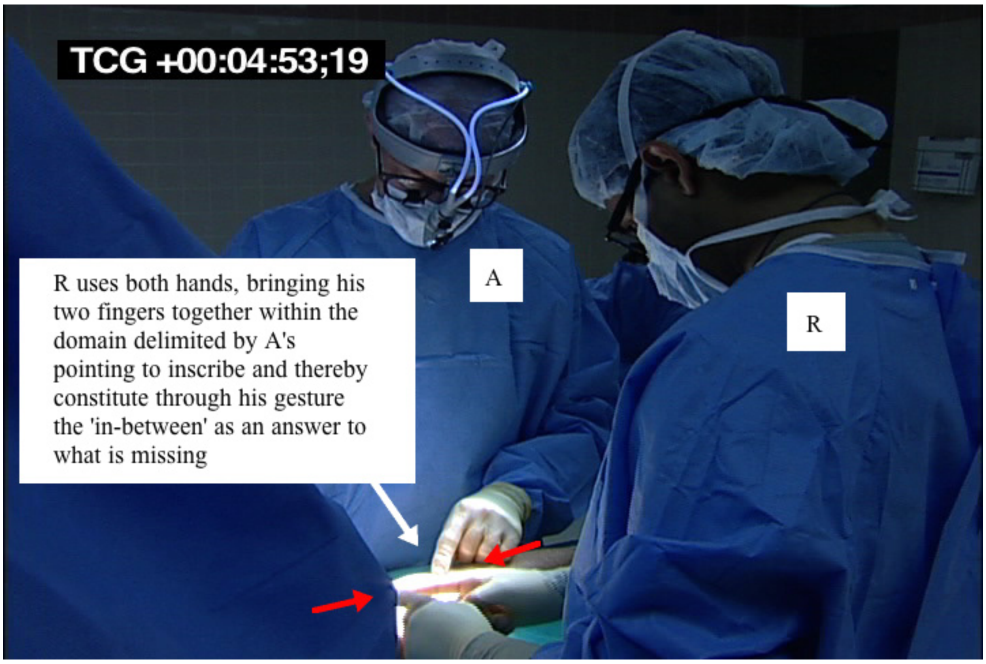
R responds to A's query by pointing to the location of the vein and to an alternative location for where the artery might be located. The spatial deictic work done by the pointing and the projected objects these gestures were designed to locate are ambiguous as answers to A's query. There are a number of possibilities. The vein and the artery referenced in talk and gesture may be considered to be features of the arm in its current pre-operative state or may refer to features of the arm as it is projected to be. The ambiguity is made problematic by the problematic status of the reference to the artery in line 16. The artery, as a relevant referent, is properly an object of surgical interest in the construction of the fistula and is not typically of concern to the dialysis nurse whose task is to insert two needles into what will become the matured vein. It may be the case that R is resisting A's attempt to cast him in the role of a dialysis nurse and is speaking in terms of surgical relevancies for the production of the fistula. It may be that R is simply unable to respond adequately even from the perspective of a dialysis nurse and is casting about to produce some kind of response other than, "I don't know."

```
17   A:      We- we- we're actually don't even [care about
18   R:                                        [kxhmm
19   A:      the artery .hhh I mean (.) we- (2.0) we've got
20           this got this cephalic vein
21   R:      Mm mhm
22   A:      Now think about it now .hhh (.) and you're the
23           dialysis nurse and over the next (.) five years
24           you're gonna be putting needles in this thing
25   R:      Mm mhm=
26   A:      =Okay so (.) we want it to matu::re (0.6) we know the
27           cephalic vein goes from here↑ (1.2) to here.
```




```
28          ⌈So fr'm here all the way up to here (.) oka:y↑
29   R:     ⌊Mm mhm
30   A:     ⌈So
31   R:     ⌊Right
32          (2.0)
33   A:     What are we missing
```

A holds this position, bracketing a region of the patient's arm between the pointing of his left and right hands. In doing so, he projects the region that, upon successful completion of the surgery, will come to contain the object he wants R to identify, i.e. the matured vein that is the intended product of the surgery. The extent of the gestured region indicates something about the size of the matured vein, which is a relevant consideration for the current surgery since, as is indicated in lines 22 through 24, this region will be an ongoing worksite for the dialysis nurse and the patient over the next five years. Having established the relevant region, A indexes the region he has defined with his pointing and at line 30, calles on R to indicate what needs to be in the space he has delimited that is not yet present. R responds with an agreement token, "Right", at line 31 but does not elaborate. He does not indicate that there needs to be an object in the region indicated by A's hands nor does he provide a description of that object. This prompts A to recycle his query in line 33.



R: The in between
A: Yeah we're missing the in between right (.)
exactly
(1.0)
A: We're missing this ↑who::le leng[th here okay so
R: [Mm mhm
A: .hhh sump'n is wro::ng

The question, "What are we missing" is made sensible because of A's sustained gesture. A has defined the space delimited by his gesture as a space that is missing something. The sense of an absence is made relevant by the fact that there had been an earlier surgery that was to have made it possible for the cephalic vein in the arm to mature, a surgery which was unsuccessful in achieving this aim. The question calls on R to consider the requirements of a dialysis nurse and assess the pre-operative arm for what would need to be present to satisfy those requirements. R responds to A's query at line 34 with "The in between". As he says this, he uses both hands, bringing his two fingers together within the domain delimited by A's pointing to inscribe and thereby constitute through his gesture the in between as an answer to what is missing. This answer is immediately affirmed in lines 35 and 36 allowing A to then more precisely characterize the extent of the missing structure and conclude that there is "sump'n is wrong" with the current state of the patient's pre-operative arm.

DISCUSSION

The participants co-present in this scene did considerable work to collaboratively produce the description of what was wrong with the patient's arm. What was wrong is that the "in between" was missing, i.e., a matured region of vein that under normal circumstances would have been easily accessible to a dialysis nurse between the upper arm where the vein enters the body and the area above the patient's elbow where the initial anastomosis was constructed. The reason why the vein had not matured was that a stenosis had occurred (at the location on the patient's arm marked by an X) which prevented adequate blood flow to occur and produce the matured vein. The attending surgeon wanted the resident to describe how the current pre-operative arm might look problematic to a dialysis nurse, thereby emphasizing the purpose of the surgery in terms of the subsequent usability of an anatomical artifact that would emerge as the result of a successful surgery.

One of the interesting features of this interaction is the way a non-present actor is made relevant to the ongoing interaction. There are a number of ways that an actor can introduce a non-present actor into an interaction. One way is to simply talk about that actor, describe actions he or she performed, etc. Another way is to invoke the non-present actor by reporting the speech of that actor, as when some says "And John said, "I thought he might have it." In such a case, the actor is animated by a speaker producing talk as that actor's speech. A third way is for a participant in the scene to actually animate the role of the non-present actor, to "become" the absent party. These different ways of introducing a non-present actor to an interaction are consequential for the kind of perspectives that their presence affords. Presenting a narrative about another person or reporting the speech of a non-present actor provides no way for the non-present actor to actually participate in the ongoing interaction among co-present participants. Such participation requires the presence of the non-present actor. There are only two ways to achieve such participation. One is to make the actual actor present, the other is for one of the co-present actors to take on the role or animate the identity of the non-present actor. This is precisely what the attending surgeon asks the resident to do, animate the identity of the dialysis nurse in a way that would allow the nurse's perspective to actively participate in the ongoing interaction.

In this paper, we have seen how gestural work, combined with both the spatial and personal indexicals in the talk serve to constitute a site of activity in at least three ways, as a site of prior activity, as the current site of participation and as a projected site of usability. It is in the combination of personal and spatial deictics in talk and in embodied action that usability becomes a relevant consideration for co-present participants in the scene. In this way, we can consider usability to be an interactional achievement, produced for consideration as relevant through the interactional work of co-present and non-present actors involved in patient care.

At a more general level, one can argue that we have examined certain methods of instruction involving the production of multiple temporal perspectives and different participation frameworks achieved as part of the accomplishment of joint work. One important way the CSCL can advance and produce meaningful results is to first understand the nature of collaborative learning. To do so can only provide further insight into ways that we can support collaborative learning through the implementation of technological interventions. Thus, collaborative learning of the sort described here is the very kind of activity that needs to be understood in CSCL if the field is to advance.

Usability is an inevitable concern and relevance in the conduct of all design work. The surgical construction of a proper transfusion site for kidney dialysis is no exception. In this paper, we examined how the actors, in the course of their work, constituted the sense and relevance of the usability of the surgically achieved structure they were working to construct. As a site for both learning and work, the operating room afforded us the opportunity to examine how usability, which is a critical design consideration, can be used as a resource for learning in interaction. In our detailed analysis of the interaction among participants (both co-present and projected) we sought to describe a particular case of how usability was achieved as a relevant consideration for surgical education in the operating room. In doing so, we hope we have demonstrated a set of members' methods by which actors establish and provide for the relevance of the projected needs of projected users as part of developing an understanding of their current activity.

ACKNOWLEDGMENTS

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Texts-In-Interaction: Collaborative Problem-Solving in Quasi-Synchronous Computer-Mediated Communication

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Abstract. Quasi-synchronous chat consists of the production and posting of text messages in an online environment. It differs from face-to-face talk-in-interaction in a number of important ways that are significant for participants in the chats and methodologically in terms of the way analysis can be conducted and the kinds of analytical claims that can be made. The perspective adopted in this paper is that chat interaction can be considered the computer-mediated production and reading of texts-in-interaction. However, since the production of a posted text is usually not available to anyone but the author of that text, I am not concerned with the production of posted texts. Rather, I am concerned with the way texts, as produced artifacts, are organized to be read by recipients. In particular, I consider ways in which quasi-synchronous chat postings provide instruction in their design for how they are to be read by recipients of these postings.

Keywords: Quasi-synchronous online chats, reading, interaction, collaboration, conjoint participation.

INTRODUCTION

In a quasi-synchronous online chat, (Q-SOC), postings are not meant to be ‘heard’. Instead, *they are designed to be read* by those who participate in the chats. Because the composition of posted texts is not witnessable to anyone other than the actor who is typing the text, recipients only read text as presented to make sense of it. In F2F, we witness the false starts, the repairs, and all manner of difficulties in getting things said. There is no particular equivalent in Q-SOC. Recipients do not see the false starts, the erasures or corrections a writer performs because the writer’s actions are unavailable to readers. All recipients see is the completed text as the finished product of the writing process. This difference between Q-SOC and F2F is consequential for how participants make sense of what they are doing when they are reading, writing and posting text messages during chats. The analytical consequence of participants’ inability to use the production of texts as an interactional resource is that only that which is posted as the enduring record of their interaction can be examined.

Reading’s Work

In their seminal work on online chats as interactional phenomena, Garcia and Jacobs (1998, 1999) have noted that turn-taking, turn-allocation and repair in Q-SOC differs significantly from the way that turn-taking, turn-allocation and repair are performed in F2F (Garcia and Jacobs 1998, 1999). The most important conclusion to be drawn from Garcia and Jacobs (1998, 1999) is that Q-SOC are not, in fact, “speech” exchange systems. Rather they are “text” exchange systems that display, in the online posting of texts, the organization of interaction among participants in these chats. While there are certain similarities to F2F conversational speech exchange systems, the differences between them are significant to the way that interaction is achieved.

The interactional work done during Q-SOC consists of posting and reading text messages. Posted messages are *designed to be read* by recipients. These texts are contingent, situated and produced to be interactional resources in quasi-synchronous online chats. This contrasts with face-to-face interaction in which speakers speak, recipients listen to the production of that speech and collaborate through their talk and other observable resources (gesture, etc.) to collaboratively constitute, make sense of, and participate in the emergent interaction. In computer-mediated quasi-synchronous online chats, *the actors’ work of posting and reading text messages is how they organize, constitute and participate in chats.* Rather than interact through emergent talk, they interact by reading and producing for posting texts and text fragments. According to Livingston (1995),

> "The work of reading is the work of finding the organization of that work that a text describes. The contextual clues in a text offer the grounds, from within the active participatory work of reading, for finding how those clues provide an adequate account of how the text should be read." (p. 14).

Thus a text is organized to inform and instruct readers with regard to how it is to be read. Each text provides clues for how readers are to make sense of it and, in the case of Q-SOC, how they are also to make sense of it in relation to previously posted texts.

DATA

The data I inspect for this analysis consist of time-stamped chat logs of math problem solving sessions sponsored by the Math Forum of Drexel University. The chats were advertised, sponsored and conducted by the Math Forum as part of its participation in the Virtual Math Teams (VMT) research project, an NSF funded project at Drexel University.[1]

Time-stamped logs of the chats were recorded at the Math Forum server that received the posted messages. The text messages as they were posted to the server were available for inspection, the sequence of their posting and the durations between postings in the sequence. For the purposes of this analysis, the use of chat logs alone for analytical inspection is consistent with the assumptions made about the interactional environment of Q-SOC.

These chats usually involved two or more participants and a facilitator. The participants oriented to and understood that the chat had a specifically declared institutional 'purpose' and affiliation to which they oriented and by which they managed themselves and were managed by the facilitator. This so-called 'purpose' was to collaboratively work together in the chat to produce solutions to posted math problems. This was made evident in the way that participation in the chats was allocated and managed by the participants and the staff at the Math Forum. Access to PoWwows (these online chat sessions) was available only on specific occasions and through the auspices of the Math Forum. The participants had 1) self-selected to visit the Math Forum website and 2) self-selected to register for PoWwows. Participants were screened in advance of their participation with respect to their level of math proficiency and were informed of the purpose and so-called 'rules' of the chat.

ANALYSIS

Garcia and Jacobs (1999) and Schönfeldt and Golato (2003) have prepared discussions of classic conversation analytic concerns with respect to chats. These include turn-taking, turn-allocation and repair. In this analysis, I consider the way that participants managed their participation in the chat to do problem-solving work as a collectively and collaboratively achieved outcome. What makes this analytically interesting is that certain interactional resources by which actors constitute themselves as a collectivity in talk-in-interaction (Lerner 1993) are not available in Q-SOC. The reason for this has to do with differences in the technologies that support and sustain these different systems of interaction. For example, it is impossible to collaborate in the conjoint production of any given text posting, although it is possible to conjointly constitute a sensible sequence of postings. Furthermore, chat participants cannot monitor recipients for how they make sense of that as that post is being produced. The sense they make derives exclusively from the way these texts are designed to be read.

In Q-SOCs, the production, transmission and receipt of posted text messages are separable actions. The most significant consequence of this is, as Garcia and Jacobs (1999) point out, that the monitoring and execution of these actions are more loosely linked to the actions of other chat participants than the monitoring and execution of conversational actions among interlocutors in F2F interaction. Furthermore, where violations of projected next-turn actions are treated as repairable or accountable matters in F2F interaction, they are routinely treated as artifacts of the technology by which Q-SOCs are achieved and thus do not always warrant the production of repairs or accounts. Of course, repair happens in chats, but its organization and achievement are subject to the technical constraints that govern the posting of messages (Schönfeldt and Golato 2003).

[1] "The VMT Project investigates issues of online collaborative math problem solving by extending the Math Forum's popular "problem of the week" service for use by small groups of students." (http://mathforum.org/wiki/VMT/). "The Math Forum is a leading center for mathematics and mathematics education on the Internet. The Math Forum's mission is to provide resources, materials, activities, person-to-person interactions, and educational products and services that enrich and support teaching and learning in an increasingly technological world" (http://www.mathforum.org/about.forum.html).

COLLABORATION AS READING'S WORK

Written texts in quasi-synchronous online chats are recognizable as utterance-like constructions that make use of textual rather than spoken resources to provide for their intelligibility. The work that these texts do is accessible and made intelligible in the way they are designed to be read and in the way interactants come to read them.

Extract 1

The second extract from a problem solving chat affords the opportunity to examine in detail certain chat features that emphasize the textual properties of chats and how these properties impact interaction. In this excerpt, we can see how participants in the chat organize themselves through their postings to begin work on the problem of the week (shown in Figure).

Ame (8:02:54 PM): Ok I guess we can start now
Fir (8:02:57 PM): just a minute. i'm uploading it
Azn (8:03:01 PM): ok
Lif (8:03:02 PM): ohk
Eef (8:03:02 PM): ***alright***
Ame (8:03:04 PM): Sure thing

The fragment begins with an invitation from Ame to begin working on the math problem that is presented as an assessment of the readiness of all participants. This assessment is localized as Ame's position and is epistemically downgraded to a possibility that others would be expected to confirm or deny ("I guess we can …"). Furthermore, it begins with an activity transition marker "Okay" and is addressed to recipients as a collectively through the use of the first person inclusive plural pronoun "we". By including all these elements in a single posting, Ame presumes that recipients can recognize this as both an assessment of recipients readiness to take up the math and as a bid to actually do so. It is only by *reading* this posting in a way that allows it to be interpreted as such an assessment and bid that recipients come to treat it as such. Evidence that they do is provided by the responses produced.

Fir's posted response is designed to be read in two parts: the first part "just a minute," calls for recipients to temporarily refrain from starting and the second part "i'm uploading it" provides a warrant for his request, and serves to 1) challenge Ame's presumption that all are ready to begin and 2) constitute what being ready to "start now" might mean for recipients. The indexical term "it" is not identified and is the activity of "uploading it" is treated as relevant and intelligible to recipients. Even if recipients agree to wait "a minute", there is nothing to prevent them from examining the problem or working on it "offline" at their various locations. This leads us to consider the question, 'What is being regulated by this request?' I would argue that what is being regulated in Fir's post is the activity: 'working on the problem conjointly'.

The suspension of conjoint consideration of the problem is temporally bounded by what participants take to be an appropriate duration for uploading and inspecting the problem. Such a suspension of conjoint consideration of the problem could be problematic for participants if it extends beyond some appropriate duration. Furthermore, the suspended conjoint consideration is treated as something members are capable of performing, thus implying that it is not problematic for participants. Yet it remains to be seen at this point of what such conjoint participation might consist.

Eef (8:04:05 PM): ***r we ready yet?***
Ame (8:04:31 PM): We should start talking
Eef (8:04:40 PM): ***yes, i conker***
Lif (8:04:51 PM): has anyone come up withan equation or expression to solve for n

After a short time of approximately a minute or so, Eef poses a query to all recipients as a collectivity, asking them "r we ready yet?" (8:04:05 PM). Ame puts forward an affiliative position "We should start talking" which is endorsed by Eef. This sequence of postings is followed by a post at 8:04:51 PM from Lif who formulates the first query regarding the problem. With this move, and without postings indicating any objection from other recipients, participants in this PoWwow collaborated to begin conjoint consideration of the problem.

The posting by Lif at 8:04:51 PM also serves to identify for participants what conjoint consideration of the problem might be for them, i.e., coming up with an equation for deriving values for the variable n. This formulation relies on participants' familiarity with the problem in its textual representation and this method of interaction using text messaging. Thus, Lif's posting embodies the presumption that others can interpret "n" appropriately as the variable in the mathematical expressions contained in the problem text.

Eef then produces a post that suggests that he had used the quadratic equation and calls on any recipient, who also used the quadratic equation, to post an acknowledgment.

Eef (8:05:14 PM): ***did n e 1 else use the quadratic equation?***
Azn (8:05:28 PM): i kinda did...
Eef (8:05:35 PM): ***me 2***
Ame (8:05:39 PM): I got a inequality
Azn (8:05:46 PM): n^2 + 4n + 4...

The abbreviational forms used by Eef, "n e 1" for "anyone,"are typical of chat abbreviations but also points to the importance of readings work. In particular, "n" and "1" in this post are designed to be read as keystroke-saving abbreviations that rely on similarity of sound when pronounced rather than similarity of form. This reliance on spoken forms for textual representation underscores how speaking can be used as a textual resource in chat.

Azn acknowledges using quadratic equations as a first effort but the modifier "kinda" and the ellipsis combine to suggest the possibly he did not get very far. The ellipsis and other such markers are textual indexical phenomena whose sense is determined by their use in postings. (An alternative sense of the ellipsis emerges only as a result of a subsequent post by Azn, which is discussed below.)

In the next post, Eef explicitly declares that he used the quadratic equation. Doing so served to constitute a sub-association of participants who had pursued this strategy. Ame, on the other hand, indicates that he had taken a different approach, implicated by the reference to an "inequality." The subsequent posting by Azn describes the quadratic equation he had deployed. This sequence of postings at this point is a fairly typical example of the complexity of sequencing faced by participants who have no access to the work others do to compose their messages. Azn's post at 8:05:46 PM relevantly can be seen as a continuation of his posting at 8:05:28 PM. This posting in fact modifies the sense of the ellipsis in the 8:05:28 PM posting, shifting its sense from one of marking uincertainty to projecting an subsequent continuation, and providing grounds for suspecting that the ellipsis in the 8:05:46 PM posting also may be projecting a continuation.

Despite the fact that Ame appears to have used a different approach from the others, all three participants at that point are busy describing systematic and mathematically coherent approaches for obtaining a value for n. Fir however used trial and error:

Fir (8:06:08 PM): i don't know what ur talking about! i just picked numbers out ofthe air:-[
Fir (8:06:14 PM): :-

Fir's two postings are a complaint with an account and emoticon, followed by a post consisting solely of an emoticon. Emoticons are textual objects used to convey the emotional valence of a posting. As semiotic resources, they constitute text-based interpretive methods for use by authors and readers. At this point, Fir uses the resources available to an author of text messages and that recipients will recognize to indicate 1) he, Fir, is having a problem with what they are doing and 2) that he is not able to engage with others in what they have begun as conjoint collaboration. This leads to the next post by Ame:

Ame (8:06:21 PM): Lets start over
Fir (8:06:27 PM): please do
Ame (8:06:27 PM): Who thinks they got the farthest
Eef (8:06:28 PM): ***alright***
Fir (8:06:39 PM): i finished it.
Ame (8:06:43 PM): Great
Lif (8:06:46 PM): wonderful

The suggestion to "start over" leaves implicit what needs to be restarted though Fir, in the next posting, appears to understand clearly what is meant. The proposal appears to call on recipients to stop pursuing their discussion in terms of mathematical strategies and to restart using different mathematical resources that would allow Fir to participate in particular ways. Again, the collective plural pro-term is implicated in the construction, amplifies Ame's proposal as a way of reasserting the collaborative nature of their association.

Rather than wait for others to display agreement, Ame queries any recipient to take a position as having gone "the farthest", presumably toward solving the problem. Ame's query constitutes another framework for conjoint collaboration that is organized around the solution rather than the strategy used to produce the solution to the problem. Interestingly, Fir, for whom participation had been problematic, then declares that he "finished it" (8:06:39 PM) implying that he is now in a position to participate.

Eef at 8:06:28 PM appears to be responding to Ame's previous suggestion at 8:06:21 PM that they "start over". Because sequencing of postings is not under the control of participants but is determined by the server (Schönfeldt, and Golato 2003) and because participants cannot witness the production of text messages by others (Garcia and Jacobs 1999), dislocations of text messages occur. Where this would be treated as a candidate for repair in a face to face interaction, it is deemed to be part of reading's work to sort out the threading of postings as they arrive on the computer screen.

DISCUSSION

In Q-SOC, posted texts are written to be read. They emerge as part of a sequence of postings and are produced to be read in a certain order. As such, they are a means of engaging in interaction with other posters of text messages. Chats are similar to talk in that they both involve the production and organization of sequences of meaningful actions. Where they differ is in the kinds of actions performed and the sequential organization of that performance.

In chat, participants cannot examine or experience the production of each other's postings. Therefore, a strict sense of the sequentiality of posted texts is often suspended and the coherent threading of posted text messages is achieved by participants as postings are posted and read (O'Neil & Martin, 2003). Because many chat systems retain posted messages for recipient review at any time, reading's work need not rely on a strict sense of sequentiality since prior texts can be recovered. One consequence of this is that the nature of turn taking and the work required to determine the threading of postings is a normal part of reading's work in Q-SOC.

Finally, the way reading's work is accomplished is part of the way participation is organized in chats. Collaboration and conjoint participation in Q-SOC are achieved primarily by posting messages to which others respond. Collectivities emerge through and are implicated by the use of collective inclusive pro-terms in the texts and in the way that participants display their alignments by posting messages of their own. It is only through postings and the way that these postings are organized to be read that collaborative and conjoint work is achieved.

Deictic and indexical work is achieved differently in text messages than in face to face interaction. One of the features of indexical work in face to face interaction is the way that deictic and indexical utterances rely on embodied action to give specific and local sense to spoken utterances. Embodied action is not available as a resource in text messages. One way that such activity is approximated in textual terms is the use of emoticons and other such textual devices. Other ways that we have seen in this paper include reliance on shared documentation, labeling of diagrams and reference to these labels, etc.

This work represents a first step in CSCL to understand chat as text-exchange system. In considering how to design text exchange systems to promote collaborative learning, it is important that we begin to understand the way such text exchange systems are currently used. This way we can see how participants organize and manage their interactions in textual terms. In so doing, we will be in a better position to consider the requirements of such a system based on how systems are actually used, rather than on how we think they should be use.

ACKNOWLEDGMENTS

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Analyzing and Supporting Collaboration in Cooperative Computer-Mediated Communication

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Abstract. Two methods for fostering collaborative behavior are compared: a feedback-mechanism to scaffold collaborative behavior, and use of distributed learning resources. Based on recent research on what constitutes effective collaboration behavior, we developed a coding scheme to categorize learner-learner interaction as collaboration. In a collaboration environment for learner dyads specifically implemented to test our hypotheses, a human observer identified, in parallel with students' interactions, instances of real collaboration, and gave online feedback. In the same two-factorial design, we varied the resources available to the partners. The influence of these interventions on outcomes related to knowledge acquisition, problem-solving, group climate and collaborative behavior was tested. Results suggest there are benefits in providing a feedback approach in fostering collaboration and enhancing problem-solving quality.

Keywords: Cooperative Learning, Feedback Research, Problem-Based Learning

APPROACHES TO SCAFFOLDING COLLABORATION

Why does collaboration in learning groups need scaffolding? The main reason is that individuals in a group do not automatically cooperate and act as a group. This is particularly the case for groups where the members have not worked together as a team before, are formed for a comparatively short time, and work under conditions where individual learning goals are predominant. These are all characteristics typical of group work in classrooms and other instructional settings, face-to-face or net-based. Under such conditions, scaffolds are needed in order to get group work going, to mitigate disorientation and reduce cognitive load.

The problem of poor peer interaction is well known in face-to-face (ftf) collaborative learning. With the use of typed, text-based computer-mediated communication this problem is likely to be increased. It is much more difficult to establish, perform and maintain basic cognitive mechanisms like turn taking and grounding. In addition, (and especially) social mechanisms like building positive interrelationships, establishing a group identity etc. are afflicted. One way to address this problem, not discussed any further in this study, is to teach collaboration and communication skills directly, as a pre-requisite for group work (e.g. Rummel, Spada, Hermann, Caspar & Schornstein, 2002). Another, more widely used, approach is to scaffold collaboration.

A number of methods for scaffolding collaboration have been developed. In order to structure these approaches, we suggest the taxonomy depicted in Figure 1. A general distinction is made in this taxonomy between scaffolds that are (instructional) design-based (all decisions are made before the collaboration begins and there is a blueprint for how collaboration will be conducted) and those that are management-based (the major decisions are made based on observations from learners' ongoing interaction, and decisions are made at "run time").

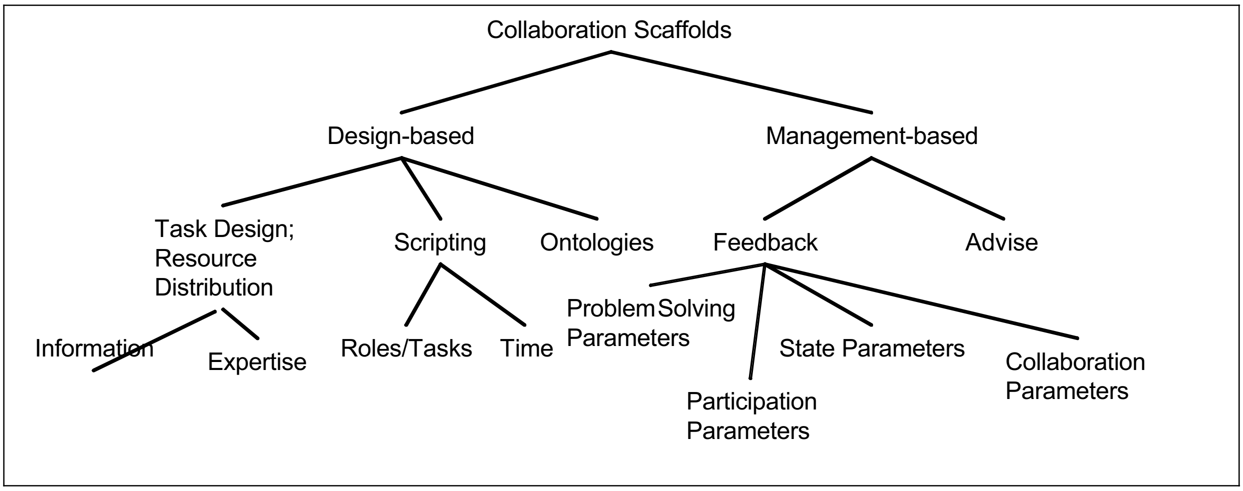


Figure 1: Approaches to Scaffolding Collaboration

Design-based Scaffolding

One method to scaffold collaboration by design involves the selection of specific tasks and resource distributions. Examples are Group Jigsaw (Aronson, 1984), Reciprocal Teaching (Palinscar & Brown, 1984) or Problem-Based Learning (e.g. Barrows, 1985). The rationale behind this approach is that students are forced to collaborate in order to accomplish a goal because of task demands and the manner in which information necessary for accomplishing the task is distributed. An elementary method is to distribute expertise among group members in early stages of group formation (e.g. Hermann, Rummel & Spada, 2001; Rummel et al., 2002). As this is not always possible (for example, when ad-hoc groups are formed) other methods have to be taken into account. A second and more applicable method is to vary resources (for example, the learning material). This method implies that only groups in which members exchange their resources or put them together can successfully complete a (learning) task. Komis, Avouris and Fidas (2003) or Muehlenbrock (2001) provide examples of this methodology by distributing learning resources for collaborative problem solving among learners. In the study of Komis et al. (2003) this intervention did not automatically lead to better learning outcomes (in this case, quality of solutions) compared to dyadic groups with individuals owning all relevant material. However, groups with distributed resources were more active, exchanged more contributions and became more involved in discussion.

Another approach that is often used is *scripting*. Scripting of collaboration (such as assigning specific roles to the members of a team) has proven effective in order to enhance turn-taking (Pfister & Mühlpfordt, 2002; Reiserer, Ertl & Mandl, 2002), elaborate design rationales (Buckingham Shum, 1997), and increase reflection (Diehl, Ranney & Schank, 2001). Reiser (2002) differentiates between two basic mechanisms of these scaffolding techniques: providing structure and problem orientation. Structured communication is one method that can be used to guide learners in terms of an optimized behavioral model (for example problem solving heuristics) or a coordinated exchange between several learners. Furthermore, the attention of learners can be drawn to relevant aspects or elements of a collaborative problem-solving process. Thus, scaffolding and scripting can avoid irrelevant or distracting tasks, strategies and processes.

Scripting as a scaffolding mechanism, however, is not always beneficial. Learner guidance in problem solving can also limit the degrees of learners' freedom. Reiser (2002, p. 263) states: "However, given the importance of connecting students' problem solving work to disciplinary content, skills, and strategies, it may also be important to provoke issues in students, veering them off the course of non-reflective work, and forcing them to confront key disciplinary ideas in their solutions to problems." In addition, structuring of discourse always involves the interruption of natural discourse. Scripting often requires external guidance on sequencing or categorization of contributions without an underlying, empirically proven rationale for the structuring method itself (Reimann, 2003). Providing groups with specific communication and collaboration *ontologies* is the third approach to design-based scaffolding we would like to discuss. Ontologies specify a vocabulary in a kind of notation for expressing information that can be exchanged. A classical example is the IBIS notation (Conklin, 1993), developed to support computer-supported collaborative decision making and organisational memory (for an application to CSCL see, for instance, Zumbach & Reimann, 2002). Dan Suther's work on how external representations affect collaboration is particularly relevant to understanding the importance of ontologies for CSCL. Ontologies are also important for management-based approaches to scaffolding, on which we will focus next.

We think that the design-based scaffolding approaches are particularly appropriate for groups that are working together for the first time and/or whose members have little domain knowledge. In such circumstances, strong external guidance can help members to focus on the task and to avoid extrinsic cognitive load. For groups that are supposed to work together over longer periods of time (such as problem-based learning teams) and/or groups where learning about collaboration is as important as completing the problem solving tasks, collaboration management approaches seem more appropriate.

Collaboration Management

Scaffolding based on collaboration management works with "run time" data gleaned from tracing the (on-line) interaction between group members. A number of approaches have been developed, ranging from the provision of dynamic feedback of participation behavior all the way to complex advice systems (see Soller et al. 2003). Focusing on feedback approaches and our own research, we (Zumbach, Mühlenbrock, Jansen, Reimann & Hoppe, 2002; Zumbach & Reimann, 2003) pursued the analysis of collaborative learning for feedback purposes in order to foster computer supported collaborative learning. In previous work, we used a methodology of tracking user data, aggregating them and feeding them back to groups in order to enrich their available resources by means of their recent collaborative efforts. A major rationale for this method is that a group's recent work is too valuable to be forgotten or unused and that traces of learners' own behavior provide the best source for learning through reflection. We argue that is not sufficient to provide groups with access to shared artifacts; and that what is needed is access to the development of these artifacts over time (problem solving history). In addition, group members need to be provided with information about their interaction and communication behavior, if we are to expect that learning about adequate collaboration and communication is to take place.

Information about learners' collaborative performance can be traced on a number of dimensions. A first dimension is *problem solving*: how does the contribution of a group member change the problem state and contribute to the solution (e.g., Zumbach & Reimann, 2003)? A second dimension is *participation*: how often, in what sequence, around which topics do members contribute to the group's work (Barros & Verdejo, 2000)? A third dimension concerns members' *emotional and motivational state*, or well-being. We (Zumbach et al, 2002, Zumbach & Reimann, 2003) have been able to show that enriching CMC by means of dynamic motivational/emotional parameters of group members helps to positively influence the group climate as well as individuals' motivation (Zumbach, Hillers & Reimann, 2003) and, thus, contributes to groups' well-being functions (cf. McGrath, 1991; McGrath & Hollingshead, 1994). A fourth dimension along which feedback can be provided is *collaboration behavior* proper: how does the action of one group member affect other group members' interaction behavior? Of particular interest in this regard is knowledge sharing (Soller, 2004).

Major challenges for the feedback approach are the (automatic) identification of collaborative acts and avoiding cognitive load problems. While previous research (in particular by Mühlenbrock (2001) and Mühlenbrock and Hoppe (1999), see also Komis et al., 2003 for a similar analysis approach; and Barros and Verdejo, 1999) has shown that collaborative acts can be identified automatically by screening users' interface actions for certain patterns, methodological problems remain. For instance, with these bottom-up approaches it is impossible to identify when a certain behavior does not take place. However, from a communication point of view, *not* reacting in a certain manner can carry important communicative information. Even if such problems were overcome, learners' may still not profit from the feedback because of cognitive load and information overload. Feedback information must be presented (on limited screen space) to a team of people who work on, often complex, tasks in a manner that is easily understandable. Visualisation techniques (e.g. Donath, Karahalios, & Vigas, 1999) become particularly important.

STUDY: COMBINING DESIGN-BASED AND MANAGEMENT-BASED SCAFFOLDING

Design- and management-based approaches to scaffolding can easily be combined and, given that they address different issues and phases of group work, this should probably occur. This study analyses how combining the distribution of learning resources (a design approach) with providing feedback on collaboration behavior (a management approach) affects various parameters of collaboration. Varying both factors in one experimental design allows us not only to assess the effects of combining the two approaches, but also to study interactions between the two factors.

Identifying Collaboration

Analysing collaboration behavior requires us to define units of analysis that capture interaction among group members. (Aggregated) observations on individual participation behavior and assessment of individual psychological states are not sufficient. Barron and Sears (2002) emphasize the role of sequence and interdependence of learner contributions. They suggest that collaboration be regarded as a sequence of different actions and depending reactions (based on a categorization scheme similar to the suggested definition of single actions provided by Barros & Veredejo, 2000). Soller and Lesgold (1999, 2000) also use such a categorization. Leaving a conceptual and abstract level, they give precise suggestions on actions that can be defined as “collaborative events”. Soller and Lesgold (1999) define three basic categories of collaborative learning skills (Active Learning, Conversation and Creative Conflict) and eight dependent subskills (Request, Inform, Motivate, Task, Maintenance, Acknowledge, Argue and Mediate) with each specifying detailed actions.

Table 1: Operationalization of collaborative events (as used in this study).

	Action of Person 1	Reaction of Person 2	Reaction of Person 1 (to Person 2)
A1	proposal (related to problem) [1, 2, 3] also: contraproposal [1, 2, 3]	agree/ accept [1, 3, 7]	
		or	
A2		support [1]	
		or	
A3.1		propose a next step [1]	agree/ accept [1, 3, 7]
			or
A3.2			support [1]
			or
A3.3			propose a next step [1]
			or
A3.4			document the proposal [1]
		or	
A4		document the proposal [1]	
		or	
A5.1		query, challenge [2]	modify proposal (for solution) [2]
			or
A5.2			assert or justify or explain (in this case a further positive reaction of person 2 is necessary) [2]
			or
A5.ex			agree, bear out (in this case: no collaboration) [1]
		or	
A6		request time (e.g. for documenting or thinking about) [1]	agree/ accept [1, 3, 7]
		or	
A7		elaborate (active) [2, 6]	
		or	
A8		elaborate (passive) [2, 6]	perform [2]
		or	
A9		ask (in case of lack of understanding) [1, 2, 7]	restate or repeat [2]
B1	ask for help advice [2, 3, 4]	inform [2, 3]	
C1	shift focus to a new aspect [2]	agree/ accept [1, 3, 7]	
		or	
C2		clarify/ negotiate [1, 2, 3]	agree/ accept [1, 3, 7]
D1	encourage partner or peer group [2, 5, 8] support group cohesion [2, 5, 8]		
E1	refer to emotional-motivational process [2, 4, 5, 8]	acknowledge [1, 2, 3, 7]	
		Or	
E2		Answer (referring to contribution) [2, 3]	
F1	coordinate task (steps for solution) [8, 9]	agree/ accept [1, 3, 7]	
		Or	
F2		clarify/ negotiate [1, 2, 3]	agree/ accept [1, 3, 7]
G1	reflect on group processing or analyze group performance [5, 9]	agree/ accept or answer [1, 3, 7]	
		Or	
G2		clarify/ negotiate [1, 2, 3]	agree/ accept [1, 3, 7]
H1	construct meta-knowledge/ reflect on distribution of knowledge [8]	agree/ accept or answer [1, 3, 7]	
I1	drag text block in shared workspace (chat) [2, 5, 7]	continue to work with text	

Notes:[1] cf. Barron & Sears (2002); [2] cf. Soller & Lesgold (2000); [3] cf. Barros & Verdejo (2000); [4] cf. Barron, Martin, Roberts, Osipovich & Ross (2002); [5] cf. Johnson & Johnson (1996); [6] cf. Kneser, Fehse & Hermann (2000); [7] cf. Clark (1996); [8] cf. Reinmann-Rothmeier & Mandl (1999); [9] cf. Welch & Tulbert (2000).

Starting from these definitions and approaches, we developed a coding schema for defining actions to be understood as a “collaborative event” (see Table 1).

Based on interaction chains, Table 1 shows the categories derived from a literature review for dyadic learning in terms of action-reaction-patterns (references to the underlying literature are in the note at the bottom of the table).

Letters A to I in Table 1 describe nine different possible ways to start collaboration (resulting in 26 possible action-reaction chains). All utterances, for example, in category A classify openings with a proposal for a problem solution (or all openings in category F represent coordinative contributions). Each code stands for another chain of interactions and is a unique collaborative event. The following examples should demonstrate the use of the coding scheme: In one of the sessions participant A stated in the chat (translation): “I need more information on the physiological background of depressive disorders. Can you help?“. Participant B answered: “Yes of course. There is something with the neuro-transmitters. According to my resources there might be a relationship between Serotonin, Noradrenalin, Dopamine, Acetylcholine and depressive disorders (…).” The example is according to our coding scheme a B1 event with A asking for help/advise and B sharing requested information. In another example participant B dragged some text into the chat for A who did not have any need for the pasted text because it was not relevant to the problem. In that case no collaborative event has been coded (in case of pasting a “useful” text this would have been an I1 event). Of course one finds longer interaction chains in the data. Our coding scheme does not account for such macro-structures, but breaks them down into elementary components, i.e. “collaborative events”.

Development of a computer supported learning scenario integrating distributed resources and collaboration feedback

Based on the considerations mentioned above, we developed a computer supported learning scenario for dyadic problem solving. The technical platform was an HTML-based interface with several components (see Figure 2). Each learner had (via a Web browser) access to a frame page with several integrated components. The first component was a window containing tasks and the learning material (HTML; left upper corner of Figure 2). The second component was a text editor where solutions to the presented problems had to be developed (left lower corner in Figure 2). The third component was a chat window for possible collaboration purposes (right space in Figure 2). The fourth and last component was an MS Excel© based counter providing feedback about the number of collaborative events (lower right corner).

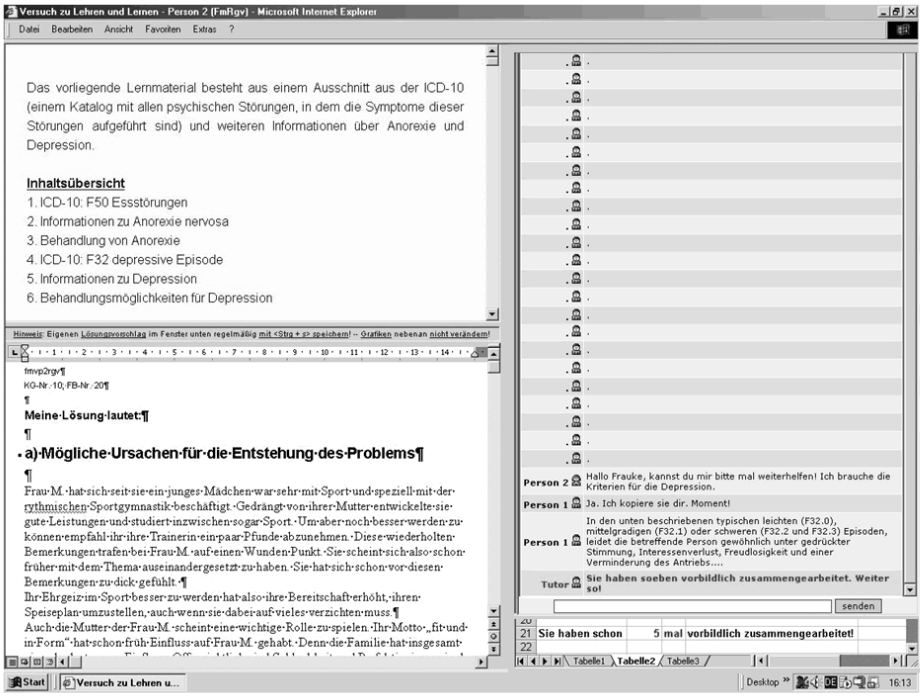


Figure 2: User Interface for individual and cooperative learning.

In order to test the effects of our methodology, we used a cooperative learning scenario in dyads with underlying principles of Problem-Based Learning. For operationalization of our feedback approach on collaborative events we had to use experimenter-based analysis of feedback due to shortcomings of automatic analysis methods related to semantic interpretation of learner-learner interaction. Thus, a trained experimenter who synchronously analyzed discourse in the chat window, monitored learners working in distributed dyads. In the case of a sequence of contributions in accordance with the categories presented in Table 1, the tutor posted the message "You have successfully cooperated! Keep on!" (in the study this was written in German) and the counter of collaborative events was raised. There was no other interference by the experimenter.

Learners were randomly assigned to pairs and conditions and participated synchronously in different rooms. After an introductory pre-test, participants were introduced into the learning environment. We assigned each student the same task, which was to solve a problem in the field of clinical psychology in a written essay (with the text editor). The problem itself was a text only case description about a woman with a co-morbid disorder (depression and anorexia nervosa). Learning objectives with regard to this problem included knowledge about cause, diagnosis, development and therapy of depression and anorexia nervosa as well as relationships between both disorders. The resources to solve the task consisted of passages of a study book for clinical psychology. These passages were digitalized and provided together with the case description as an HTML-document (in the upper left corner of the user interface; see Figure 2).

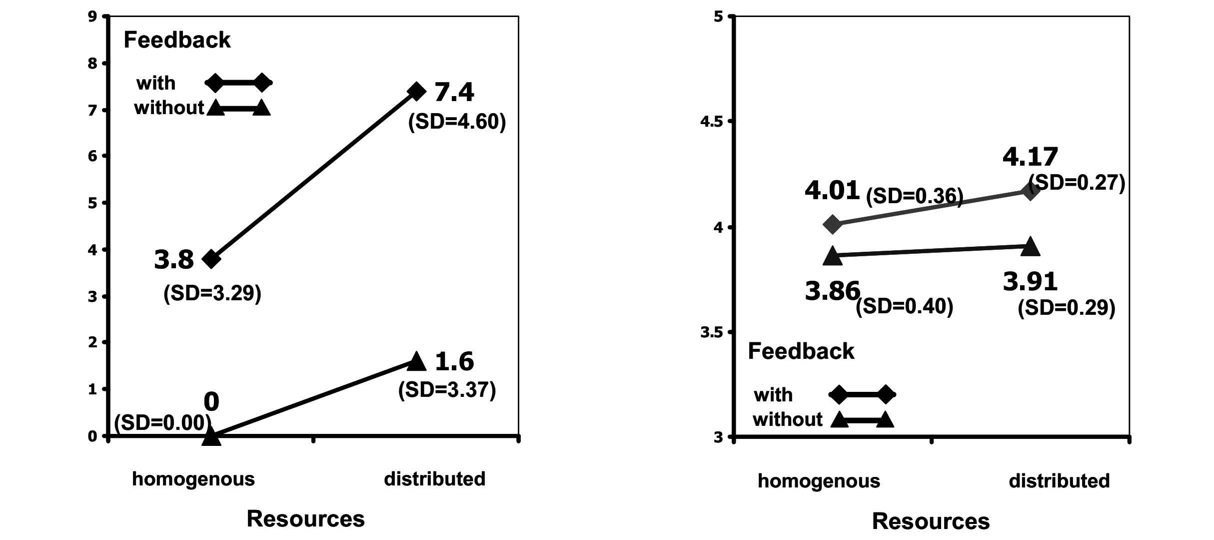
The main purpose of this study was to measure the influence of two basic interventions on the quantity of collaboration and cognitive outcomes as well as group climate: first, the influence of distributed learning resources and second, the availability of feedback on collaborative events (i.e. an underlying 2 X 2 factorial design). The rationale behind this choice was that prior work (e.g. Zumbach & Reimann, 2003; Zumbach, Hillers & Reimann, 2004) has emphasized the role of feedback related to problem solving, participation and state parameters, but not collaboration parameters themselves. Furthermore, there is still need of research on design-based scaffolding related to task design and resource distribution. Thus, the first factor was the variation of the learning resources (homogenous versus distributed). In one condition (homogenous resources), each learner had access to the complete learning material relevant for solving the case. In a second condition, one participant had access only to relevant passages about depressive disorders and the other participant of the dyad to the learning material related to anorexia nervosa. As both parts were single chapters in the underlying textbook, they were simply divided. The second factor was the availability or absence of feedback on collaborative events. In one condition, the dyadic learning groups received feedback as operationalized and described above. In a second condition, the experimenter analyzed collaborative feedback events but no feedback was provided (the visualization was also removed from the user interface). In the introductory part of the experiment, participants received information about their task and the possibility of cooperating with a peer over the computer interface. They were not informed about the different factors of this study (for example, they did not know, in the condition concerned with distributed learning resources, that the other person had different resources that might be additionally relevant for solving the given problem). As each participant was assigned the task of producing an individual case solution, the approach was cooperative rather than collaborative.

Main Results

Our major goal was to show that distributed learning resources as well as collaboration feedback improve collaborative learning and, thus, contribute to learning success, the quality of problem-solving and have a positive influence on group climate. Overall, 40 participants (7 men and 33 women with a mean age of 24.5 years; most of them students at the University of Heidelberg) took part in this study. In a pre-test we assessed participants' prior knowledge with a test related to the learning objectives of the case solution (six open and twenty multiple choice questions with each half assessing knowledge about depression and anorexia nervosa). The same test was used as post-test. In the post-test we also assessed the group climate experienced by participants using an adopted subscale of the Medical School Learning Environment Survey (Lancaster, Bradley, Smith, Chessman, Stroup-Benham & Camp, 1997; Marshall 1978; some sample items are "The learning experience made students feel a sense of achievement.", "The experience of the learning environment made students feel depressed." or "The learning experience made students value themselves."). We expected by means of fostering collaboration to establish a kind of cognitive but also a positive social interdependence. Thus, we expected processes of cognitive as well as social grounding that should contribute to groups' well-being functions (cf. McGrath, 1991). We also took into account the number of collaborative events as well as each participant's quality of problem solution as dependant variables. Overall, participation in this study took about 2 ½ hours with pre- and pos-test lasting about one hour altogether.

Results related to absolute events of collaboration revealed a poor rather than extensive cooperation among individual group members (see Figure 2, left side). In the condition with homogenous resources and no collaboration feedback there was no collaborative event at all. The several interventions led to an increased number of collaborative interactions (Chi-square (df=1) = 3.86, $p<.05$; calculated on group level). The highest amount was in the condition with distributed resources and collaboration feedback. The numbers are, in general, very low (each dyad had about 1 ½ hours time for problem-solving/cooperation). Several aspects might explain this. First, students had to read the case description and scan the learning material (which contained about 8500 words overall; learners were encouraged to read selectively). This took a major part of the available time. Second, the chat limited exchange between students not only to short sentences, but also allowed them to exchange longer paragraphs of the learning material or their own problem solutions. Most interaction chains (considered here as collaborative events) included exchange of major text parts.

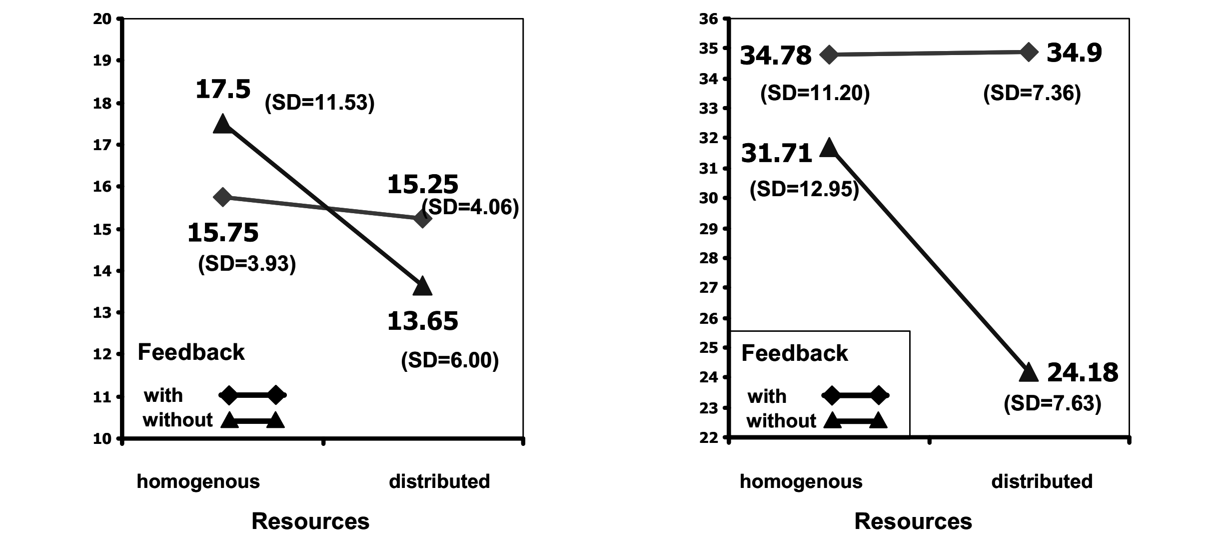
Another dependant variable was the group climate as experienced by the learners. There was no effect of the factor “distributed resources” but a marginal effect of “collaboration feedback” (F(1, 38) = 3,744, p< .061): dyads that received this kind of feedback experienced the group climate better than dyads without this feedback (see Figure 2 right).



Number of collaborative events *Group climate*

Figure 2: Results on collaborative events and group climate.

We were also interested in learning outcomes. Results of the standardized knowledge tests (pre- and post test) were compared in order to compute an overall score of knowledge acquisition from before to after the treatment. Results reveal no significant effects (see Figure 3, left). Participants in the condition with distributed resources and no collaboration feedback received the lowest scores. A lack of collaboration as well as additional learning material (owned by the other partner of the dyad) could explain this.



Knowledge increase *Problem-solving quality*

Figure 3: Results in knowledge tests and problem solving.

For analyzing the quality of problem solutions provided by the participants, we developed an expert solution (including causes, diagnoses and therapy of depression and anorexia nervosa as well as interrelationships between both disorders). Two expert raters compared participants’ case solutions with the expert model using a scoring scheme (r_{corr}=0.97). Participants in dyadic groups with collaboration feedback scored significantly higher than those in groups without feedback (F(1, 38) = 4,687, p< .037; see Figure 3, right). There was no significant effect of distributed versus homogenous resources (F(1, 38) = 1,353, n.s) as well as no significant interaction effect. The following table shows results on correlations of dependant measures.

Table 2: Correlation matrix of dependant variables.

	Number of collaborative events	Group climate	Problem-solving quality	Knowledge (post test)
Number of collaborative events	-	0.56**	0.24	-.02
Group climate	0.56**	-	0.18	-0.17
Problem-solving quality	0.24	0.18	-	0.39*
Knowledge (post test)	-.02	-0.17	0.39*	-

Notes:
Spearman R correlation. * = p<.05; **p<.01

SUMMARY AND DISCUSSION

Based on previous research on CSCL we integrated two major scaffolding approaches into a learning environment in order to assess the combined effects of such approaches, and their interaction effects. There are many approaches that try to describe collaboration in terms of learner behaviour. In the literature review we provided an overview on recent theoretical and empirical approaches. Based on this review we developed a rationale for defining and categorizing chains of interaction as single, collaborative events. Based on these working definitions we conducted a study testing the influence of feedback on collaboration and distributed learning resources in a network-based cooperative learning environment.

In a 2 x 2 factorial experiment we tested the influence of distributed learning resources as well as feedback related to collaboration on outcomes of knowledge acquisition, quality of problem-solving, group climate and number of collaborative events in a network-based cooperative learning scenario. Learners in dyads had to solve a single case following a Problem-Based Learning approach. Results suggest that a distribution of learning resources and feedback about collaboration enhance collaborative behaviour (compared to homogenous learning material and/or no collaboration feedback). Although we could not find an enhancement in knowledge acquisition using a common test format, we were able to show that the feedback approach led to significantly better problem solutions. Results related to group climate also suggest that feedback on collaborative events could foster collaboration itself and, thus, positively influence group climate.

Taken together, results suggest that by distributing learning material, collaboration can be positively influenced but this will have no substantial effect on cognitive outcomes or group climate. In addition, monitoring students interaction behaviour and providing feedback on collaboration triggers further collaborative behaviour and influences problem-solving processes as well as group climate.

Let us try to put this study into a more general perspective. If knowledge is created and re-created primarily through the interactions between people, as a distributed view of cognition suggests, then the analysis of collaboration behaviour constitutes a major prerequisite for the understanding of learning and knowledge. To the extent that collaboration is essential for learning, the analysis of collaboration is essential for meta-learning, for learning about learning. If learners are to be empowered to reflect upon their collaboration behaviour and to become strategically aware collaborative learners, they ought to be provided with concepts and tools for analyzing their collaborative learning. Our approach constitutes a first step in that direction. It is only a first step because in this study we provided minimal information to learners about their collaboration: only the number of 'exemplary collaboration episodes' was fed back to the students. We did not provide conceptual information (the kind of collaboration that was observed) at this stage. Further studies will address this.

Another shortcoming, at least from a pragmatic perspective, is the fact that we used a human observer to analyze learners' interactions. This is clearly not an approach that will scale up to multiple dyads working in parallel or to groups with more than two participants (where communications begin to take place in parallel between sub-groups). The dilemma here is that software, so far, has not surpassed humans in their ability to identify meaningful interaction patterns, or has come close. However, for more or less well-defined discourse areas and small group sizes, it can be expected that semantic techniques, and also statistical text analysis approaches (text mining) can be brought to bear on this task.

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