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Editors Claire O'Malley, Daniel Suthers, Peter Reimann, Angelique Dimitracopoulou

COMPUTER SUPPORTED COLLABORATIVE LEARNING PRACTICES

CSCL2009 CONFERENCE PROCEEDINGS

9th INTERNATIONAL CONFERENCE CSCL

JUNE 8-13, 2009, RHODES

UNIVERSITY OF THE AEGEAN, GREECE

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INTERNATIONAL SOCIETY OF THE LEARNING SCIENCES

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Introduction

The CSCL conference and the International Society of the Learning Sciences (ISLS)

The international conference on Computer-Supported Collaborative Learning 2009 (CSCL2009) is the 9th in a series of international CSCL conferences, representing the growing interest of researchers and educators in social environments based on information and communication technologies and in the formal or informal learning that takes place during interactions around or through such technologies. It represents an established multidisciplinary field of technology based collaborative learning, which emerged about 20 years ago[1] and has developed together with the rapid growth of communication technologies.

The first CSCL conference began at Indiana University, Bloomington, USA (1995) and continued biannually with conferences associated with the University of Toronto, Canada (1997); Stanford University, USA (1999); the University of Colorado at Boulder, USA (2002); the University of Bergen, Norway (2003); the National Central University, Taipei, Taiwan (2005) and Rutgers University, New Jersey, USA (2007). In between, a European conference on CSCL (EuroCSCL) was organized at 2001, in Maastricht, Netherlands. This was the first to be held outside North America since 1995, and which heralded subsequent conferences being held not only in the USA and Europe, but also across the world.

CSCL has grown over the years and become one of the two established conferences organized by the International Society of the Learning Science (ISLS). The society incorporated as a non-profit professional society in 2002, uniting the traditions started by the Journal of the Learning Sciences, the International Conferences of the Learning Sciences (ICLS), and the Computer-Supported Collaborative Learning Conferences (CSCL). It has also recently embraced the International Journal of Computer Supported Collaborative Learning (ijCSCL). It offers publications, conferences and educational programs to the community of researchers and practitioners who use cognitive, socio-cognitive and socio-cultural approaches to studying learning in real-world situations and designing environments, software, materials and other innovations that promote deep and lasting learning (www.isls.org).

CSCL 2009 is being held in the south-eastern part of Europe, in Rhodes, Greece, at the University of the Aegean — a new and dynamic University (established in 1989) whose Faculties are distributed across five different islands in the Aegean archipelagos.

The present volume of CSCL2009 Proceedings

By tradition, CSCL conferences include a lively mix of invited keynotes, submitted paper sessions, submitted symposia, workshops, panels, posters, demonstrations etc, covering timely and important issues of interest to the community and reporting recent research findings. This tradition is constantly improving and being enriched.

Typically, the heart of every scientific conference consists of the papers (full and short papers) that are selected after a rigorous review process and presented during the conference. The corresponding papers for CSCL2009 are found in the CSCL2009 Conference Proceedings (distributed by LuLu & Amazon). The companion volume of the CSCL2009 Community Events Proceedings crystallizes and provides community memory of the rich variety of events that take place beyond the papers, including Symposia, Panels, Interactive Events and Posters. They also contain publications related to the Pre-Conference Events: Tutorials, Seminars and Workshops, including the Doctoral Consortium Workshop and the Post Doc & Early Career Workshop.

Contributors to the present Volume

The CSCL conference is a major international event that gathers together people involved in all aspects of the field of technology-based collaborative learning, including research, education, training, work and technology. CSCL2009 participants include experienced as well as early career researchers, designers, educators, industrial trainers from various disciplines including education, cognitive, social and educational psychology, didactics, subject matter specialties, computer science, linguistics and semiotics, speech communication, anthropology, sociology, design, etc. The contributors to the CSCL2009 conference hail from all around the world, but mainly from Europe, North and South America, the Middle East, Asia and Australia.

CSCL2009 received a total of 344 submissions across all categories, 231 for full and short papers and 113 for Posters, Panels, Symposia and Pre-Conference events. Each paper had three reviewers. Papers were assigned to reviewers based on expertise in the specific area and to ensure representation and diversity along various dimensions, such as disciplinary background and cultural context. All reviews were overseen by the program chairs and one of the three program chairs provided a meta-review for each paper.

[1] The first international workshop on CSCL was held in Maratea, Italy, in September 1989, organized by Claire O'Malley. Another early workshop on CSCL was held in Carbondale, Illinois, USA.

Of the 151 submissions in the full paper category, 40 were accepted as full papers (2 of which for interactive presentations), 37 as short papers (9 interactive), and 16 as posters. The resulting acceptance rate for full papers was 26%, which is in keeping with the highest quality conferences in cognate fields. Of the 80 submissions as short papers, 19 were accepted as short papers (5 interactive), and 19 as posters. Of the 231 submissions in the full and short paper categories, 60% of the first authors were first-timers to the CSCL conference.

Taking into account some papers that were subsequently withdrawn, the final program consisted of 38 full papers, 55 short papers and 53 posters. We thank all of the many reviewers of the submissions for the conference for their dedication, considered and timely reviews. Your efforts are appreciated by the whole CSCL community.

CSCL2009 Conference Theme (CSCL Practices) and Thematic Categories

The CSCL conferences, in general, focus on issues related to formal and informal learning through collaboration, promoting productive collaborative interactions with the support of a variety of information and communications technologies. The CSCL community studies and designs effective technological CSCL tools, as well as related educational interventions.

The themes of the work represented in the present volume reflect to a large extent the central concerns of the overall field of CSCL:

- understanding collaborative and learning processes by empirical study;
- designing and developing technology based collaborative learning environments, focusing also on activities and the design of scaffolding, accompanying teachers' and moderators' strategies;
- designing and implementing interventions (in educational systems and various professional communities);
- theories and analytic approaches;
- methodologies for analysis, research design and design processes.

The CSCL2009 conference theme 'CSCL Practices' emphasizes practices relating to technology based collaborative learning in three major areas:

- learning in typical educational institutional structures: preschool and primary education, secondary education, higher and adult education, as well as special education;
- learning in workplaces, such as professional training in companies, but also informal learning during working processes;
- learning in everyday life: informal learning in everyday practice, involving the use of networked wired and wireless technological devices and especially the Internet, in the every day life of students or adults.

All three areas above are represented in the present volume. In addition, some work refers to the practices of the CSCL research community itself, analyzing in a direct or indirect way its social nature, influences and dominances.

Most research papers represented in this volume address formal education (primary, secondary, higher education, special needs education), teachers' education as well as vocational training. However, some papers also address informal learning in everyday life, as well as the field of workplaces such as medicine, sciences, small or medium sized enterprises.

One of the purposes of the conference theme was to identify the current educational, professional or everyday practices that evolve within close or wider collaboration among small or larger groups or communities. The aim was also to identify 'naturally' emerging practices (in the sense that they were not designed, suggested or implemented by researchers). This purpose is consistent with the identification of how specific tools or platforms are appropriated, as well as of motivation, de-motivation, usability or effectiveness issues. Also, in some cases, the aim is not only to understand the origins of highly motivated current activities and practices, but also to examine whether and how these motivated aspects could be incorporated in designed environments (technological and/or human).

More specifically, in the following paragraphs, we present briefly the specific topics of the present volume. We have organized the proceedings into thematic sections in order to provide readers of the proceedings (particularly newcomers to CSCL) with an overview of major areas of research. There are four major thematic categories: Studying Practices of CSCL, CSCL Practices in Educational Settings, Practices Associated with Technologies, and Designing for CSCL Practices. Each of these has several sub-categories. These categories were derived from the sessions of the CSCL 2009 conference program, but differ somewhat from that program. The program was generated under constraints such as collecting 90 minutes of paper presentations together, not requiring that an author be in two places at once, and so on. These constraints do not apply to the proceedings, freeing us up to further optimize the thematic organization. The reader who is interested in retrieving individual papers may also utilize the table of contents or index to look up papers by title or author, or search the PDF version of this document.

Part I: Studying Practices of CSCL

Papers in this section focus on understanding or exposing what is happening in interactions, usually in small groups, rather than on the setting of interaction, hypothesis testing or efforts to design for interaction. There are three sub-themes. A number of papers concern the Practices of Learning in Interaction, offering analyses that expose the practices through which people collaborate and learn through interaction. Many of these papers are influenced by ethnomethodology or conversation analysis. They include papers exploring in detail the moment-by-moment interactions between participants, mediated by shared representations that themselves evolve through interactions between participants and with the representations. Another set of papers in this section concerns Influences on Knowledge Construction Practices. These papers generally take an experimental or variables-oriented approach to analyzing influences on process and outcome measures. At first blush these papers seem to take an approach that is diametrically opposed to the first – a caricature might be experimental (educational) psychology vs. ethnomethodology. However, these two contrasting themes have been with us since the earliest days of CSCL and it is testament to the maturity of the field that few nowadays would see them as being mutually exclusive research options. In this regard, the third sub-section in this part of the proceedings may offer rapprochements. This section involves various Approaches to Analyzing Interaction. All of these papers introduce explicitly some approach to analyzing interaction. This section gives the reader an idea of the diverse approaches taken to understanding interaction. Papers include the development not only of analysis methods, but also of visualizations and interactive tools to support the researcher in making sense of, analyzing and presenting information from complex datasets, often involving many participants, their dialogues and interactions with computational tools. Other papers in this section are more theoretical, developing further notions of mediation that have their origin in traditional approaches such as socio-cultural psychology and activity theory. Yet others propose new methods of analysis involving the latest technologies such as eye tracking. What is common to all these papers, and an emerging theme in CSCL and the learning sciences more generally, is that analysis of learning outcomes without analysis of process data is no longer productive and illuminating. We need to understand how to relate detailed analysis of interactions to changes in learning prior to and following interventions. We still have a long way to go as a field in developing effective techniques for this, but the papers in this volume represent an excellent start.

Part II: CSCL Practices in Educational Settings

Papers in this section have a more explicit emphasis on how CSCL takes place in the practices of formal educational settings. As is the case with all of the themes, many of these papers could have been classified elsewhere, but all highlight some aspect of the educational setting. A number of papers focus on conceptual change in learning in Science and Mathematics Education, focusing on procedural learning versus conceptual change, issues of curriculum design, amongst others. A cluster of papers concern CSCL in Higher Education, exploring practices of discussions and debates by university and college level students mediated through CMC. There is some overlap in this respect with the previous section on Influences on Knowledge Construction Practices, but here the emphasis on practice in the higher education setting is more explicit. Continuing this theme, the papers in Teacher Communities and Professional Development focus on support for teachers' professional development and practices, and teacher communities. The final sub-section concerns papers that take us to a different level of Systemic Perspectives on Practice, examining organizational, institutional and cultural issues, as well as one paper providing a holistic practices-oriented perspective on system design.

Part III: Practices Associated with Technologies

Papers in this section look explicitly at how the characteristics of technology relate to the practices of using that technology. The papers in the sub-section on Shared Workspaces and Tangibles explore issues common to both ‘virtual’ and ‘tangible’ shared workspaces, such as coordination of participants’ activity. The papers on Mobile Devices and Sensors share a common thread in terms of computing that is distributed between people and geographic locations. This is a nice follow-up to shared workspaces because in some of these the mobile devices are used for distributed coordination. A collection of issues converge: not only mobility of devices, but the interaction between personal devices, and learning as distributed across classroom and other locations. The papers on Games and Simulations concern practices of learning in simulated environments. The papers on Social Software and Wikis represent a growing concern and interest in CSCL with Web 2.0 technologies, examining how social software supports learning.

Part IV: Designing for CSCL practices

The papers in this section focus on the effects of interventions on collaborative learning. While other papers also examined interventions, here the focus on design is stronger. A major are of current CSCL research is Scripting Collaboration, or various methods of guiding learners' collaboration, usually through explicit means. The papers on Scaffolding Learning Practices also scaffold learning practices, but in ways that are less explicit or perhaps more flexible than scripts. In the section on Argumentation and Discussion the common focus is designing for learning through conflict and negotiation in interaction. In the section on Peer Awareness, Self-regulation and Coaching the papers examine some aspect of how awareness tools can influence the self-regulation or peer coaching of collaborative learners.

The field of CSCL is diverse and vibrant. We hope that this collection of papers conveys the multi-vocality of CSCL while also providing a hint of how its diversity has some coherence as an interdisciplinary field.

Acknowledgements

We would like to thank the different committees and groups of people that have contributed to the work reflected in the present volume of CSCL2009 Conference Proceedings.

First of all, we would like to thank all those who contributed by their research to this conference: not only the junior and senior scientists whose work is represented in this volume, but also all those who are interested in CSCL and have submitted full and short papers. We would like to thank the 177 reviewers that reviewed all submitted papers.

The CSCL2009 Steering Committee members have contributed in various aspects of the conference organization, while members of ISLS Board have enriched the whole process with their ideas and advice. Finally, in terms of the organization of the CSCL2009 conference in general, we would like to thank all the members of the Hellenic organizing committee and especially thank all the members of the Learning Technology and Educational Engineering Laboratory (LTEE lab) of the Faculty of Humanities in Rhodes, that have devoted a great part of their time during the last year.

Cordial and sincere thanks to all!

Claire O'Malley, Daniel Suthers, Peter Reimann, and Angelique Dimitracopoulou

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PART I

STUDYING PRACTICES OF CSCL

Interaction Analysis of Dual-Interaction CSCL Environments

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Abstract: In order to collaborate effectively in group discourse on a topic like mathematical patterns, group participants must organize their activities so that they have a shared understanding of the significance of their utterances, inscriptions and behaviors—adequate for sustaining productive interaction. The need for participants to coordinate their actions becomes particularly salient in dual-interaction environments, where, e.g., chat postings and graphical drawings must work together; analysts of such interactions must identify the subtle and complex ways in which meaning making proceeds. This paper considers the methodological requirements on analyzing interaction in dual-interaction environments by reviewing several exemplary CSCL studies. It reflects on the nature of social organization, grounding and indexicality that frame the interaction to be analyzed.

"Everything that can be counted does not necessarily count;
everything that counts cannot necessarily be counted." Albert Einstein

The Problem of Social Organization in Dual-Interaction Collaboration Spaces

A central issue in the theory of collaborative learning is how students can solve problems, build knowledge, accomplish educational tasks and achieve other cognitive accomplishments together. How do they share ideas and talk about the same things? How do they know that they are talking about, thinking about, understanding and working on things in the same way? Within CSCL, this has been referred to as the problem of the "attempt to construct and maintain a shared conception of a problem" (Roschelle & Teasley, 1995), "building common ground" (Baker et al., 1999; Clark & Brennan, 1991) or "the practices of meaning making" (Koschmann, 2002). We have been interested in this issue for some time: (Stahl, 2006) documents a decade of background to the Virtual Math Teams (VMT) research reported here—chapter 10 (written in 2001) argued the need for a new approach and chapter 17 (written in 2002) proposed the current VMT project. During the past six years (see Stahl, 2009), we have been studying how students in a synchronous collaborative online environment organize their interaction so as to achieve intersubjectivity and shared cognitive accomplishments in the domain of school mathematics.

Knowledge building in CSCL has traditionally been supported primarily with asynchronous technologies (Scardamalia & Bereiter, 1996). Within appropriate educational cultures, this can be effective for long-term development of ideas by learning communities. However, in small groups and in many classrooms, asynchronous media encourage exchange of individual opinions more than co-construction of progressive trains of joint thought. We have found informally that synchronous interaction can more effectively promote what we term "group cognition"—the accomplishment of "higher order" cognitive tasks through the coordination of contributions by individuals within the discourse of a small group.

In CSCL settings, interaction is mediated by a computer environment. Students working in such a setting must enact or invent ways of coordinating their understandings by means of the technological affordances that they find at hand. The development and deployment of these methods is not usually an explicit, rational process that is easily articulated by either the participants or analysts. It takes place tacitly, unnoticed, taken-for-granted. In order to make it more visible to us as analysts, we have developed an environment that makes the coordination of interaction more salient and captures a complete record of the group interaction for detailed analysis (Stahl, 2009, Ch 15 & 16). In trying to support online math problem solving by small groups, we have found it important to provide media for both linguistic and graphical expression. This resulted in what is known within CSCL as a *dual-interaction space*. In our environment, students coordinate their text chat postings with whiteboard drawings. A careful analysis of how they do this reveals as well their more general methods of social organization.

In this paper, we review approaches to dual-interaction spaces by important recent CSCL studies. The analytic thrust of these studies is to arrive at quantitative results through statistical comparisons of aggregated data. To accomplish this, they generally have to restrict student actions in order to control variables in their studies and to facilitate the coding of student utterances within a fixed ontology. We fear that this unduly restricts the interaction, which must be flexible enough to allow students to invent unanticipated behaviors (Dillenbourg & Jermann, 2006). The restrictions of laboratory settings make problematic experimental validity and generalization of results to real-world contexts. Even more seriously, the aggregation of data—grouping utterances by types or codes rather than maintaining their sequentiality—ignores the complexity of the relations among the utterances and actions. According to our analysis (Stahl, 2009, Ch 26), the temporal and semiotic relations are essential to understanding, sharing and coordinating meaning, problem solving and cognition.

While quantitative approaches can be effective in testing model-based hypotheses, they seem less appropriate both for exploring the problem of interactional organization and for investigating interactional methods, which we feel are central to CSCL theory. The effort to operationalize and quantify interactional phenomena risks reducing and reifying rich relationships into categories that fail to capture the group practices (Stahl, 2006, Ch 10). In particular, if individual chat postings are coded, then the unit of analysis becomes the individual action rather than the group interaction. Even if relations of neighboring actions are considered the often complex effects of temporally distant references upon the group meaning making is systematically ignored.

In the following, we will review studies of dual-interaction spaces in the CSCL literature in terms of their methodological orientation, underlying theoretical background and software features. The goal of our review is to offer a methodological and theoretical refinement of the conceptual frameworks underlying these studies. In the light of the common themes we identify across these studies we will argue that we need to conduct systematic case studies exploring the ways participants organize their interaction across multimodal interaction spaces in order to see how groups work on more open-ended tasks in less restricted online environments. Finally, we will propose a conceptual framework based on insights from ethnomethodology and linguistic anthropology that better suits the analytical challenges posed by the sequentially emergent and indexical nature of interactions mediated by CSCL environments with multimodal interaction spaces.

Approaches in CSCL to Analyzing Multimodal Interaction

Multimodal interaction spaces—which typically bring together two or more synchronous online communication technologies such as text chat and a shared graphical workspace—have been widely used to support collaborative learning activities of small groups (Dillenbourg & Traum, 2006; Jermann, 2002; Mühlpfordt & Wessner, 2005; Soller & Lesgold, 2003; Suthers et al., 2001). The way such systems are designed as a juxtaposition of several technologically independent online communication tools carries important interactional consequences for the users. Engaging in forms of joint activity in such online environments requires group members to use the technological features available to them in methodical ways to make their actions across multiple spaces intelligible to each other and to sustain their joint problem-solving work.

In this paper, we review existing studies in the CSCL research literature that focus on the interactions mediated by systems with multimodal interaction spaces to support collaborative work online. We have selected sophisticated analyses, which go well beyond the standard coding-and-counting genre of CSCL quantitative studies, in which utterances are sorted according to a fixed coding scheme and then statistics are derived from the count of utterances in each category. Our review is not meant to be exhaustive, but representative of the more advanced analytical approaches employed. Unlike the simple coding-and-counting studies, the approaches we review attempt to analyze some of the structure of the semantic and temporal relationships among chat utterances and workspace inscriptions in an effort to get at the fabric of common ground in dual-interaction online environments.

The communicative processes mediated by multimodal interaction spaces have attracted increasing analytical interest in the CSCL community. A workshop held at CSCL 2005 specifically highlighted the need for more systematic ways to investigate the unique affordances of such online environments (Dillenbourg, 2005). Previous CSCL studies that focus on the interactions mediated by systems with two or more interaction spaces can be broadly categorized under: (1) prescriptive approaches based on models of interaction and (2) descriptive approaches based on content analysis of user actions.

(1) The *modeling approach* builds on the content-coding approach by devising models of categorized user actions performed across multimodal interaction spaces. We look at two examples:

a. Soller & Lesgold's (2003) use of Hidden Markov Models and
b. Avouris et al's (2003) Object-oriented Collaboration Analysis Framework.

In these studies the online environment is tailored to a specific problem-solving situation so that researchers can partially automate the coding process by narrowing the possibilities for user actions to a well-defined set of categories. The specificity of the problem-solving situation also allows researchers to produce models of idealized solution cases. Such ideal cases are then used as a baseline to make automated assessments of group work and learning outcomes.

(2) The *descriptive approach* informed by content analysis also involves categorization of user actions mediated by multimodal interaction spaces, applying a theoretically informed coding scheme (Neuendorf, 2002). Categorized interaction logs are then subjected to statistical analysis to investigate various aspects of collaborative work such as:

a. The correlation between planning moves performed in chat and the success of subsequent manipulations performed in a shared workspace (Jermann, 2002; Jermann & Dillenbourg, 2005),
b. The relationship between grounding and problem-solving processes across multiple interaction spaces (Dillenbourg & Traum, 2006),
c. A similar approach based on cultural-historical activity theory (Baker et al., 1999), and

d. The referential uses of graphical representations in a shared workspace in the absence of explicit gestural deixis (Suthers, Girardeau & Hundhausen, 2003).

(a) Soller and Lesgold's modeling approach involves the use of Hidden Markov Models (HMM) to automatically detect episodes of effective knowledge sharing (Soller & Lesgold, 2003) and knowledge breakdowns (Soller, 2004). The authors consider a programming task where triads are asked to use object-oriented modeling tools to represent relationships among well-defined entities. The task follows a jigsaw design where each group member receives training about a different aspect of the shared task before meeting with other members. The group sessions are hosted in the Epsilon online environment, which includes a text-chat area and a shared workspace. The workspace provides basic shapes that allow users to diagrammatically represent entities and relationships. Participants are required to select a sentence opener to categorize their contributions before posting them in the chat window. The authors manually extract segments from their corpus where each member gets the opportunity to share the unique knowledge element he/she was trained in with other group members. Some of these episodes are qualitatively identified as ideal cases that exemplify either an instance of effective knowledge sharing or a knowledge breakdown, completely based on the results of post-tests. For instance, a segment is considered an effective knowledge-sharing episode provided a chance for demonstrating the unique knowledge element comes during the session, the presenter correctly answers the corresponding questions in both pre- and post-tests, and the explanation leads at least one other member to correctly answer the corresponding question(s) in the post-test. The sequence of categorized actions (including chat postings and workspace actions) that correspond to these ideal cases is used to train two separate HMMs for the breakdown and effective knowledge sharing cases, respectively. An HMM computes the probability of a certain kind of action immediately following another; it thus captures certain aspects of sequentiality. These models are then used to automatically classify the remaining episodes and to assess team performance. However, the method is seriously limited to recognizing connections among actions to those based on immediate sequences of codes. While this can capture adjacency pairs that are important to conversation, it misses more distant responses, interrupted adjacency pairs, temporal markings and semantic indexes. The authors apparently make no specific distinction between workspace and chat actions as they build their HMMs over a sequence of interface actions. Moreover, the relationship between object diagrams constructed in the workspace and the explanations given in chat do not seem to be considered as part of the analysis. Hence, it is not clear from the study how a successful knowledge-sharing episode is achieved in interaction and whether the way participants put the affordances of both interaction spaces into use as they explain the materials to each other have had any specific influence on that outcome. Although they were reported to be successful in classifying manually segmented episodes, HMMs computed over a sequence of categorized actions seem to obscure these interactional aspects of the coordination of chat and workspace.

(b) The modeling approach outlined in Avouris et al. (2003) and Komis et al. (2002) proposes a methodology called the Object-oriented Collaboration Analysis Framework (OCAF) that focuses on capturing the patterns in the sequence of categorized actions through which dyads co-produced objects in a shared task space. The collaborative tasks the authors used in their online study included the construction of database diagrams with well-defined ontological elements such as entities, relationships and attributes. In this problem-solving context the final representation co-constructed in the shared workspace counted as the group's final solution. The OCAF model aims to capture the historical evolution of the group's solution by keeping track of who contributed and/or modified its constituent elements during the course of an entire chat session. The authors not only consider direct manipulation acts on specific elements but also chat statements through which actors propose additions/modifications to the shared diagram or agree/disagree with a prior action. The chat and drawing actions are categorized in terms of their functional roles (e.g., agree, propose, insert, modify, etc.). The mathematical model includes the sequence of categorized actions and the associations among them. The model is then used to gather structural properties of interactions (e.g., how contributions are distributed among dyads, what functional role each contribution plays) and to trace how each action performed in the interface is related to other actions. This modeling approach differs from similar approaches in terms of its specific focus on the objects co-constructed in the shared workspace. The model captures the sequential development of the shared object by keeping track of the temporal order of contributions made by each user. However, it is not clear from the study how the model could deal with the flexibility of referential work. For instance a chat posting may refer to multiple prior postings or to a sub-component of a more complicated entity-relationship diagram by treating several elemental objects as a single object. In other words, a model trying to capture all possible associations between individual actions in a bottom-up fashion may miss the flexibility of referential work and obscure the interactional organization.

(c) Jermann (2002) employs a coding scheme to study the correlation between planning moves in the chat area and the success of subsequent manipulations performed on the shared simulation in the Traffic Simulator environment. The shared task involved students tuning red-green periods of four traffic lights in the simulation to figure out an optimal configuration to minimize the waiting time of cars at intersections. The workspace could be manipulated in specific ways by users. The workspace also includes a dynamic graph that shows the mean waiting time for the cars. The goal of the task is to keep the mean value below a certain level for two minutes. The study included additional experimental cases where dynamically updated bar charts are displayed to provide feedback to users about their level of participation. The logs of recorded sessions are coded in terms of their planning and regulatory content. The nature of the task allowed authors to numerically characterize different types of work organizations in terms of the distribution of manipulations performed on four possible traffic lights. The authors complement this characterization with number of messages posted, number of manipulations done and the types of messages as captured in the coding scheme. The study reported that dyads who coordinated their actions across both interaction spaces by planning what to do next (i.e., task regulation) and discussing who should do what (i.e., interaction regulation) in chat before manipulating the simulation performed better (i.e., achieved the objective more quickly). The interaction meters were not reported to have significant effects on promoting task and interaction regulation. The work of high performance groups are characterized with phrases like "posted more messages," "more frequent postings," "talked relatively more than they executed problem solving actions," "monitor results longer," "produced elaborated plans more frequently" in reference to the tallied codes, frequency of messages and duration of activity. Although the main argument of the paper highlights the authors' interest in sequential unfolding of regulatory moves, the way the employed quantitative approach isolates and aggregates the actions obscures the temporal connections and sequential mechanisms constituting different forms of regulation moves.

(d) Dillenbourg & Traum (2006) employ a similar methodology to study the relationship between grounding and problem solving in an online environment including a shared whiteboard and a text-chat area. In this study the participants were grouped into dyads and asked to collaboratively work on a murder-mystery task. The authors framed their analysis along the lines of Clark & Brennan's (1991) theory of grounding (at least applied at the micro level of individual utterances) and theories of socio-cognitive conflict. The study reports two kinds of uses of the dual spaces to facilitate grounding during problem solving: a "napkin" model and a "mockup" model. The authors hypothesized that the whiteboard would be mainly used to disambiguate dialogues in the chat window via basic illustrations (i.e., the napkin model). However, the authors report that the dyads used the whiteboard for organizing factual information as a collection of text boxes, and the chat component was mainly used to disambiguate the information developed on the whiteboard (i.e., the mockup model). The authors attributed this outcome to the nature of the task, which required users to keep track of numerous facts and findings about the murder case, and the difference between the two media in terms of the *persistency* of their contents. Since participants organized key factual information relevant to the problem at hand on the shared whiteboard during their experiments, the authors attributed a shared external memory status to this space and claimed that it facilitated grounding at a broader level by offering a more persistent medium for storing agreed upon facts. The study succeeds in highlighting the important role of medium persistence, even if it does not specify the methods by which students exploited such temporal persistence.

(e) Baker et al. (1999) provide a theoretical account of collaborative learning by bringing together the processes of grounding and appropriation from psycholinguistics and cultural-historical activity theory (CHAT), respectively. In their study they focus on the interactions mediated by the C-Chene software system where dyads are tasked to co-construct energy models that account for storage, transfer and transformation of energy (Baker & Lund, 1997). The models for energy-chains are constructed in a shared workspace that allows the addition of annotated nodes and directed edges. Participants also have access to a chat area that can be customized with sentence openers, which are claimed to promote reflective contributions, reduce typing effort and minimize off-task discussion. The interface is designed to allow only one user to produce a contribution in a given interaction interval. The users need to press a button to switch between dual interaction spaces. Hence the possibility of parallel or overlapping work (e.g., one user drawing on the board as the other is typing a message) is ruled out on the grounds that this would hinder collaboration. The dyads also could not overlap in typing since they need to take turns to use the dialog box where they type their messages. However, it is possible for a user to interrupt his/her partner through a special prompt, which asks whether it is okay to take the turn. If the partner agrees, then the turn is passed to the other user. The study reported that dyads who used the structured interface exhibited more reflective and focused discussion. The authors point to limitations involved with constraining user actions to fixed categories, but they argued that some of the sentence openers they used correspond to generic speech acts that were used for multiple purposes in the course of interaction.

(f) Suthers et al. (2003) investigate the *referential* uses of shared representations in dyadic online discourse mediated by the Belvedere system. This environment has a chat area as well as a shared workspace where dyads can co-construct evidence maps to represent their arguments as a set of categorized textboxes linked to each other (Suthers et al., 2001). The study compares face-to-face and online cases to investigate how dyads use the system as a conversational resource in each case as they work on a shared task that involves developing hypotheses about the spreading of a disease at a remote island. Categories for deictic uses such as finger pointing, cursor-based deixis, verbal deixis and direct manipulation of objects are identified and applied to the session logs. Based on the distributions of these categories for each case, the authors report that dyads in the online case made use of verbal deixis and direct manipulation of shared objects to compensate for the limitations of the online environment to achieve referential relationships across dual interaction spaces. Moreover, the study reports that such referential links are more likely to be observed between temporally proximal actions. For instance, a chat posting including a deictic term is likely to be read in relation to a node recently added to the shared representation.

Our review of relevant work in the CSCL literature highlights some common threads in terms of methodological approaches and theoretical orientations.[1] First, the studies we have reviewed all focus on the group processes of collaboration, rather than treating it as a mere experimental condition for comparing the individuals in the groups. Second, all studies employ a content-coding approach to categorize actions occurring in multiple interaction spaces. In most cases, representational features like sentence openers or nodes corresponding to specific ontological entities are implemented in the interface to guide/constrain the possibilities for interaction. Such features are also used to aid the categorization of user actions. The categorization schemes are applied to recorded logs and subjected to statistical analysis to elicit interaction patterns.

Despite the accomplishments of these studies, we find that their approaches introduce systematic limitations. Interactional analysis is impossible because coherent excerpts from recorded interactions are excluded from the analysis itself. (Excerpts are frequently used outside of the quantitative analysis, to introduce the features of the system to the reader, to illustrate the categorization schemes employed or to motivate speculative discussion). Moreover, most studies like these involve dyads working on specific problem-solving contexts through highly structured interfaces in controlled lab studies in an effort to manage the complexity of collaboration. The meanings attributed by the researchers to such features of the interface need to be discovered/unpacked by the participants as they put them into use in interaction—and this critical process is necessarily ignored by the methodology. Finally, most of the papers are informed by the psycholinguistic theory of common ground, and are unable to critique it thoroughly.

The Unit of Analysis

For methodological reasons, quantitative approaches generally (a) constrain subject behaviors, (b) filter (code) the data in terms of operationalized variables and (c) aggregate (count) the coded data. These acts of standardization and reduction of the data eliminate the possibility of observing the details and enacted processes of unique, situated, indexical, sequential, social interaction (Stahl, 2006, Ch. 10). An alternative form of interaction analysis is needed to explore the organization of interaction that can take place in CSCL settings.[2]

In The VMT Project (Stahl, 2009), we also focus on small-group interactions mediated by multimodal interaction spaces. However, our study differs from the work reviewed above by our focus on groups larger than dyads whose members are situated outside a controlled lab environment, and by our use of open-ended math tasks where students are encouraged to come up with their own problems. Moreover, we do not impose any deliberate restrictions on the ways students access the features of our online environment or on what they can say. Our main goal is to investigate how small groups of students construe and make use of the "available features" (Dohn, 2009) of the VMT online environment to discuss mathematics with peers from different schools outside their classroom setting. In other words, we are interested in studying interactional achievements of small groups in complex computer mediations "in the wild."

Our interest in studying the use of an online environment with multiple interaction spaces in a more naturalistic use scenario raises serious methodological challenges. In an early VMT study where we conducted a content analysis of collaborative problem-solving activities mediated by a standard text-chat tool in a similar scenario of use, we observed that groups larger than dyads exhibit complex interactional patterns that are difficult to categorize based on a theory-informed coding scheme with a fixed/predetermined unit of analysis (Stahl, 2009, Ch 20). In particular, we observed numerous cases where participants post their messages in multiple chat turns, deal with contributions seemingly out of sequence and sustain conversations across multiple threads that made it problematic to segment the data into fixed analytic units for categorization. Moreover, coming to an agreement on a code assignment for a unit that is defined *a priori* (e.g., a chat line) turned out to be heavily dependent upon how the unit can be read in relation to resources available to participants (e.g., the problem description) and to prior units (Stahl, 2009, Ch 22). In other words, the sense of a unit not only depends on the semantic import of its constituent elements, but also on the occasion in which it is embedded (Heritage, 1984). This often makes it possible to apply multiple categories to a given unit and threatens the comparability

[1] We do not intend to minimize the contributions of the particular papers or authors reviewed. On the contrary, we have selected exemplary CSCL studies in order to make a methodological comparison. The quantitative studies may be effective in pursuing their research questions, but their approaches are inadequate for understanding common ground qualitatively. Some of these authors have also adopted case-study approaches more recently; to take only examples from one of the labs, see the studies of deixis, interactional up-take and narrative structure in (Dwyer & Suthers, 2006; Suthers, 2006; Yukawa, 2006).

[2] It should be clear that we do not reject the use of coding-and-counting for pursuing appropriate research questions—such as testing models of dependent variables. However, they may be systematically unsuited to explore issues of sequential organization and group cognition, which we consider important to CSCL theory and practice.

of cases that are labeled with the same category. More importantly, once the data is reduced to codes and the assignments are aggregated, the sequential relationships among the units are lost. Hence, the coding approach's attempt to enforce a category to each fixed unit without any consideration to how users organize their actions in the environment proved to be too restrictive to adequately capture the interactional complexity of chat (Stahl, 2009, Ch 23). In addition, the inclusion of a shared drawing area in our online environment made the use of a theory-driven coding approach even harder due to increased possibilities for interaction. The open-ended nature of the tasks we use in our study makes it especially challenging to model certain types of actions and to compare them against ideal solutions.

The issue of unit of analysis has theoretical implications. In text chat it is tempting to take a single posting as the unit to be analyzed and coded, because a participant defined this as a unit by posting it as a message and because the chat software displays it as a visual unit. However, this tends to lead the analyst to treat the posting as a message from the posting individual—i.e., as an expression of a thought in the poster's mind, which must then be interpreted in the minds of the post readers. Conversation analysis has argued for the importance of interactions among participants as forming more meaningful units for analysis. These consist of multiple utterances by different speakers; the individual utterances take each other into account. For instance, in a question/answer "adjacency pair" the question elicits an answer and the answer responds to the question. To take a pair of postings such as a question/answer pair as the analytic unit is to treat the interaction within the group as primary. It focuses the analysis at the level of the group rather than the individual. As we just discussed, in online text chat responses are often separated from their referents, so the analysis is more complicated (Fuks, Pimentel & Pereira de Lucena, 2006). In general, we find that the important thing is to trace as many references as possible between chat postings and whiteboard actions in order to analyze the interaction of the group as it unfolds (Stahl, 2009, Ch 26). It is through the co-construction of a rich nexus of such references that the group weaves its shared understanding.

Relatedly, the notion of common ground as an abstract placeholder for registered cumulative facts or pre-established meanings has been critiqued in the CSCL literature for treating meaning as a fixed/denotative entity transcendental to the meaning-making activities of inquirers (Koschmann, 2002). The common ground that supports mutual understanding in group cognition or group problem solving is a matter of semantic references that unfold sequentially in the momentary situation of dialog, not a matter of comparing mental contents (Stahl, 2006, pp. 353-356). Committing to a reference-repair model (Clark & Marshall, 1981) for meaning making falls short of taking into account the dynamic, constitutive nature of meaning-making interactions that foster the process of inquiry (Koschmann et al., 2001).

Given these analytical and theoretical challenges, in studying virtual math teams (Stahl, 2009), we have opted for an alternative to the approaches reviewed above that involve modeling of actions and correct solution paths or treating shared understanding as alignment of pre-existing individual opinions. We focus on the *sequence of actions* in which participants co-construct and make use of *semiotic resources* (Goodwin, 2000) distributed across dual interaction spaces to *do* collaborative problem-solving work. In particular, we focus on the organization of activities that produce graphical drawings on the shared whiteboard and the ways those drawings are used as resources by actors as they collaboratively work on an open-ended math task. Through detailed analysis of a case study (Çakir, Zemel & Stahl, 2009), we investigate how actions performed in one workspace inform the actions performed in the other and how participants coordinate their actions across both interaction spaces. The affordances of the chat and whiteboard spaces are investigated by documenting the methods enacted by participants to address these interactional matters using the affordances of the VMT system (Çakir, 2009). In the next section we will discuss the findings of our case studies in relation to the findings and concerns of related CSCL research that we have covered in our review.

Grounding through Interactional Organization

The coordination of visual and linguistic methods (across the whiteboard and chat workspaces) plays an important role in the establishment of common ground through the co-construction of references between items in the two spaces. Particularly in mathematics—with its geometric/algebraic dual nature—symbolic terms are often grounded in visual presence and associated visual practices, such as counting or collecting multiple units into a single referent (Goodwin, 1994; Healy & Hoyles, 1999; Livingston, 2006; Sfard, 2008; Wittgenstein, 1944/1956). The visually present can be replaced by linguistic references to objects that are no longer in the visual field, but that can be understood based on prior experience supported by some mediating object such as a name—see the discussion of mediated memory and of the power of names in thought by (Vygotsky, 1930/1978; 1934/1986). A more extended analysis of the co-construction of mathematical artifacts by virtual math teams, the complementarity of their visual, semantic and symbolic aspects, their reliance on pre-mathematical practices and processes of reification into concepts are beyond the scope of this paper and require comparison of multiple case studies (see Çakir, 2009). However, for this paper it is important to understand something of how the interactional organization that we have observed in VMT functions to ground the group's understanding of their math objects as shared group achievements.

In CSCL research there has been an explicit interest in studying how affordances of online environments with multiple interaction spaces facilitate *grounding*, and how grounding processes relate to collaborative problem-solving work mediated by such online environments (Baker et al., 1999; Dillenbourg & Traum, 2006). In this section we will discuss the findings of our case studies in relation to the concerns and results reported in prior CSCL research on these issues.

As implied in the OCAF study (Avouris et al., 2003) discussed at the beginning of this paper, investigating grounding and problem-solving processes in online dual-interaction environments like VMT requires close attention to the relationships among actions performed in multiple interaction spaces. Detailed math discussions in the VMT environment present practical challenges for mathematical models that aim to exhaustively capture their relationships. For instance, graphical objects are often layered on top of each other by multiple participants. Despite this combinatoric challenge, a modeling approach can still attempt to capture all possible geometric relationships among these graphical objects in a bottom-up fashion. However, when all chat messages referring to the whiteboard objects are added to the mix, the resulting model may obscure rather than reveal the details of the interactional organization through which group members discuss more complicated mathematical objects by treating a collection of atomic actions as a single entity. Terminology is frequently co-constructed in the chat-and-whiteboard environment specifically in order to be able to refer to complexly defined math objects with a shorthand name, icon or symbol.

The challenges involved with the modeling approach are not limited to finding efficient ways to capture all relationships among actions and identifying meaningful clusters of objects. The figurative uses of the graphical objects present the most daunting challenge for such an undertaking. For instance, a specific drawing may be used as a *gloss* (Garfinkel & Sacks, 1970) to talk about an imagined pattern that grows infinitely and takes the shape illustrated on the whiteboard only at a particular stage. In the absence of a fixed set of ontological elements and constraints on types of actions a user can perform, modeling approaches that aim to capture emergent relationships among semiotic objects distributed across multiple interaction spaces need to adequately deal with the retrospective and prospective uses of language in interaction. Rather than relying upon a generic approach to modeling imposed by the researchers, our interactional approach aims to discover the "model"—or, better, the meaning—that was constructed *by the group*.

In another study discussed earlier, Dillenbourg & Traum (2006) offer the napkin and mockup models in their effort to characterize the relationship between whiteboard and chat spaces. In short, these models seem to describe two use scenarios where one interaction space is subordinated to the other during an entire problem-solving session. The complex relationships between the actions performed across both interaction spaces in our case made it difficult for us to describe the interactions we have observed by committing to only one of these models, as Dillenbourg & Traum did in their study. Instead, we have observed that in the context of an open-ended math task groups may invoke either type of organization, depending upon the contingencies of their ongoing problem-solving work. For instance, during long episodes of drawing actions where a model of some aspect of the shared task is being co-constructed on the whiteboard, the chat area often serves as an auxiliary medium to coordinate the drawing actions, which seems to conform to the mockup model. In contrast, when a strategy to address the shared task is being discussed in chat, the whiteboard may be mainly used to quickly illustrate the textual descriptions with annotations or rough sketches, in accordance with the napkin model. Depending on the circumstances of ongoing interaction participants may switch from one type of organization to another from moment to moment. Therefore, instead of ascribing mockup and napkin models to entire problem-solving sessions, we argue that it would be more fruitful to use these terms as glosses or descriptive categories for types of interactional organizations group members may invoke during specific episodes of their interaction.

Another important observation made by Dillenbourg & Traum is that the whiteboard serves as a kind of shared external memory where group members keep a record of agreed-upon facts. In their study, the dyads were reported to post text notes on the whiteboard to keep track of the information they had discovered about a murder-mystery task. This seems to have led the authors to characterize the whiteboard as a placeholder and/or a shared working memory for the group, where agreed-upon facts or "contributions" in Clark's sense are persistently stored and spatially organized. As Dillenbourg & Traum observed, the scale of what is shared in the course of collaborative problem solving becomes an important issue when a theory operating at the utterance level like contribution theory (Clark & Marshall, 1981) is used as an analytic resource to study grounding processes that span a longer period of time. Dillenbourg & Traum seem to have used the notion of persistence to extend common ground across time to address this limitation. In particular, they argued that the whiteboard grounds the solution to the problem itself rather than the contributions made by each utterance. In other words, the whiteboard is metaphorically treated as a physical manifestation of the common ground.

In our case studies we have observed that the whiteboard does not simply serve as a kind of shared external memory where the group keeps a record of agreed-upon facts, opinions, hypotheses or conclusions. In our sessions the whiteboard is primarily used to draw and annotate graphical illustrations of geometric shapes, although users occasionally post textboxes on the whiteboard to note formulas they find. While the whiteboard mainly supports visual reasoning and textual discussion or symbolic manipulation occurs chiefly in the chat stream, actions are carefully, systematically coordinated across the media and integrated within an interactionally organized group-cognitive process. The fact that there are inscriptions posted on the whiteboard does not necessarily mean that all members immediately share the same sense of those graphical objects. The group members did considerable interactional work to achieve a shared sense of those objects that was adequate for the purposes at hand. Hence, the whiteboard objects have a different epistemic status in our case studies than in Dillenbourg & Traum's experiment. Moreover, not all contents of the whiteboard are deemed relevant to the ongoing discussion by the participants. Finally, the sense of previously posted whiteboard objects may be modified or become evident as a result of current actions (Suchman, 1990). In other words, group members can not only reuse or reproduce drawings, but they can also make subsequent sense of those drawings or discard the ones that are not deemed relevant anymore. Therefore, the technologically extended notion of common ground as a placeholder for a worked-out solution suffers from the same issues stated in Koschmann & LeBaron's (2003) critique of Clark's theory. As an abstract construct transcendental to the meaning-making practices of participants, the notion of common ground obscures rather than explains the ways the whiteboard is used as a resource for collaborative problem solving.

From Common Ground to Indexical Ground

Instead of using an extended version of common ground as an analytical resource, we frame our analysis using the notion of "indexical ground of deictic reference"—a term we appropriated from linguistic anthropology (Hanks, 1992). In face-to-face interaction, human action is built through the sequential organization of not only talk but also coordinated use of the features of the local scene that are made relevant via bodily orientations, gesture, eye gaze, etc. In other words, "human action is built through simultaneous deployment of a range of quite different kinds of semiotic resources" (Goodwin, 2000, p. 1489). Indexical terms and referential deixis play a fundamental role in the way these semiotic resources are interwoven in interaction into a coherent whole.

Indexical terms are generally defined as expressions whose interpretation requires identification of some element of the context in which it was uttered, such as who made the utterance, to whom it was addressed, when and where the utterance was made (Levinson, 1983). Since the sense of indexical terms depends on the context in which they are uttered, indexicality is necessarily a relational phenomenon. Indexical references facilitate the mutually constitutive relationship between language and context (Hanks, 1996). The basic communicative function of indexical-referentials is "to individuate or single out objects of reference or address in terms of their relation to the current interactive context in which the utterance occurs" (Hanks, 1992, p. 47).

The specific sense of referential terms such as *this*, *that*, *now*, *here* is defined locally by interlocutors against a shared indexical ground. The intelligibility of such terms is based on a *figure/ground relationship* between the new action involving the indexical reference (i.e. the figure) and the sequentially unfolding context constituted by the actions that has been witnessed recently and the objects persistently available in the shared scene. Conversely, the linguistic labels assigned to highlighted features of the local scene shape the indexical ground. Hence, the indexical ground is not an abstract placeholder for a fixed set of registered contributions. Rather, it signifies an emergently coherent field of action that encodes an interactionally achieved set of background understandings, orientations and perspectives that make references intelligible to interlocutors (Zemel et al., 2008).

Despite the limitations of online environments for supporting multimodality of embodied interaction, participants make substantial use of their everyday interactional competencies as they appropriate the features of such environments to engage with other users. For instance, Suthers *et al.*'s (2003) study reports that deictic uses of representational proxies play an important role in the interactional organization of online problem-solving sessions mediated by the Belvedere system. The authors report that participants in the online case devised mechanisms that compensate for the lack of gestural deixis with alternative means, such as using verbal deixis to refer to the most recently added text nodes and visual manipulation of nodes to direct their partner's attention to a particular node in the shared argument map.

In contrast to the Belvedere system, VMT offers participants additional resources such as an explicit referencing mechanism, a more generic workspace that allows producing and annotating drawings, and an awareness feature that produces a sense of sequentiality by embedding indicators for drawing actions in the sequence of chat postings. Our case study (Çakir et al., 2009) shows that despite the online situation's lack of the familiar resources of embodied interaction, team members can still achieve a sense of shared access to the meaningful objects displayed in the dual interaction spaces of the VMT environment. Our analysis indicates that coherence among multiple modalities of an online environment like VMT is achieved through members' methodical uses of the features of the system to coordinate their actions in the interface. In particular, we observed that the witnessable details of the orderly construction of shared inscriptions (e.g., the way objects are spatially arranged in relation to each other through sequences of actions) and the deictic references that link chat messages to features of those inscriptions and to prior chat content are instrumental in the achievement of indexical symmetry (intersubjectivity) with respect to the semiotic objects relevant to the task at hand.

Through coordinated use of indexical-referential terms and highlighting actions, team members help each other to literally "see" the objects implicated in the shared visual field (Goodwin, 1994) and to encode them with locally specified terminology for subsequent use. Moreover, the integration of both modalities in this manner also facilitates joint problem solving by allowing group members to invoke and operate with multiple realizations—graphical, narrative and symbolic—of their mathematical task. Such coordinated work across modalities can be a powerful problem-solving resource since it allows participants to invoke various mathematical practices relevant to the task at hand and to make use of them in mutually elaborating ways.

To sum up, the focus of our ethnomethodological inquiry is directed towards documenting how virtual teams achieve a sense of reciprocity and coherence among their actions in an online CSCL environment with multiple interaction spaces. Our approach (Stahl, 2009, Ch 28) includes a close investigation of the moment-to-moment details of the practices through which participants organize their chat utterances and whiteboard actions as a coherent whole in interaction—a process that is generally lost in statistical analyses of multiple cases, where categorization and aggregation systematically miss the rich and vital relationships of indexicality and sequentiality. We have observed that referential practices enacted by the users are essential in the coordinated use of multimodalities afforded by such environments. The referential uses of available features are instrumental not only in allocating other members' attention to specific parts of the interface where relevant actions are being performed, but also in the achievement of reciprocity (intersubjectivity, common ground, shared understanding, group cognition) among actions in the multiple interaction spaces, and hence a sense of sequential organization across the spaces. Among the things that count in interaction are the indexical ground that is built up through interactional references that cannot be counted without destroying their sequential relationships.

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Roles of Initiators and Interaction Patterns: Exploring an Informal Online Community at the Interpersonal Plane

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Abstract: We present a study exploring learning in an informal online community (OC) for foodservice professionals according to three planes (i.e., community, interpersonal, and individual planes). Among these planes, this paper focuses on the interpersonal plane (i.e., how do participants interact with each other and what do they share through their interactions?) and highlight the importance of initiators' roles and the subsequent interaction patterns. To investigate interaction and learning processes, we collected 227 discussion threads posted in the year 2006, analyzed them through a multi-layered analysis approach, and graphically presented the results to show the complex components of interactions at a glance. Finally, we discuss the characteristics of interaction and learning processes in this OC and the relationship between initiators roles and interaction patterns.

Introduction

The purpose of this study is to explore learning occurring in an online community (OC) of foodservice professionals, which is informally structured and based on voluntary participation. Learning is looked at according to three planes (Rogoff, 1998): Community (i.e., how is this OC learning as an organization?), Interpersonal (i.e., how does learning occur between members of the OC?), and Individual (i.e., how does individual learning occur through participating in the OC?). Among these planes, this paper focuses on the interpersonal plane – *how do participants interact with each other and what do they share through their interactions?* - and we highlight in particular the role played by initiators of on-line discussion threads and the subsequent interaction patterns.

Within an OC as an environment for computer-supported collaborative learning (CSCL), members may share their experiences, interests, and knowledge through conversations. They also negotiate meanings, learn from one another, and build new knowledge through the process of discussion. This process of online interaction is mediated by discourse. Thus, Herring (2004) suggests a computer-mediated discourse analysis (CMDA) approach, which is defined as "the analysis of logs of verbal interaction (characteristics, words, utterances, messages, exchanges, threads, archives, etc.)" and more broadly, "any analysis of online behaviour that is grounded in empirical, textual observations" (p. 339) to investigate the processes of learning and interaction in online contexts.

Two approaches (Gunawardena, Lowe, & Anderson, 1997) have often characterized the study of online community and online discussion: (a) *participation analysis* using quantitative data having "value in determining who participated, how actively, and how long" (p.398) ; and (b) *content analysis* and *interaction analysis* as qualitative approaches, which allow assessing the quality of interactions and learning in an online context. Recently, social network analysis (SNA) has been considered as an analytical method to investigate the network structure (e.g., heterogeneity and size) and the patterns of interaction (e.g., Chen & Jiang, 2007; Cocciolo, Chae, & Natriello, 2007; Koku & Wellman, 2004). Along with these approaches, various methodological approaches have been explored in the study of CSCL and online community (de Wever, Schellens, Valcke, & Van Keer, 2006; Rourke, Anderson, Garrison, & Archer, 2001; Strijbos, Martens, Prins, & Jochems, 2006)

In addition, most studies regarding interaction and learning in online discussions have been conducted in formal(1) and non-formal(2) education settings, in which students' participation and interactions typically are pre-designed, assigned, and regulated by instructors. In contrast, only a few studies have taken place in informal learning(3) settings (e.g., Owen, Pollard, Kilpatrick, & Rumley, 1998; Schlager, Fusco, & Schank, 2002) and large-scale collectives (Kapur et al., 2007). The OC explored in this study is an informal entity and the members' participation is voluntary and spontaneous. Therefore it is important to characterize the features of interaction and learning process in the OC as they may reveal different patterns and outcomes, and hence serve to identify some factors enabling interaction and learning processes in CSCL environments.

Study Context: Informal Online Community

The environment for this study is an online community (OC) for foodservice professionals. It was founded in 1996 as the first OC created for the foodservice industry and continues today as the largest, most active community of foodservice professionals. Services which this OC provides include Discussion forums & chat, Employment center, Weekly e-newsletter, Daily industry news & editorials, and market reports. Among these services, to investigate the interpersonal plane, we mainly focused on members' activities in the discussion forums where more frequent, constant interactions occur. The initial purpose of the discussion forums is to offer a place to ask questions and share information about experiences, skills, and knowledge in relation to the foodservice industry.

Our previous investigation of this OC at the community plane (Heo & Breuleux, 2008) revealed that this OC is an informal entity comprised of individuals who have wide ranges of years of experience and knowledge, from experts to novices throughout different areas in the foodservice industry. The number of registrants was over 40,000 (as of 2007) and this OC has been maintained actively and developed continuously since 1996. There are important roles in this OC, including one administrator (i.e., who takes charge of administrative tasks), a few informal moderators (i.e., who take care of other members and of the atmosphere), and a sufficient number of active members. The outcome of the collaborative interaction is a shared repertoire including not only tangible resources, such as several information resources and archives from the discussion forums, but also invisible and unwritten aspects (e.g., the memory of a Christmas message and the unwritten rules).

Methods

For the interpersonal plane, we initially followed a content analysis approach (Henri, 1992), which is essential "to assess the quality of interactions and the quality of the learning experience in a computer mediated conferencing environment" (Gunawardena et al., 1997, p. 398). The discourse of discussion transcripts was analyzed through Lampert and Ervin-Tripp (1993)'s coding process, which suggests a dynamic way of constructing a coding system between the top-down and the bottom-up approaches depending on the nature of data. We also considered a multi-layered analysis. The results of the sequential analyses with multiple-layers allow explaining the content of discussion as well as the form of interactions, which are closely connected with each other.

Data Collection and Analysis

Sample discussion transcripts were selected by time in order to "preserve the richest context" (Herring, 2004, p.351). In other words, all threads, which are groups of postings including an initial message and responses to it, posted in the discussion forum of "Chefs and cooks corner" in the year 2006 (between January 2006 and December 2006) were saved and reviewed. Hence, 227 threads were collected along with the 1,818 replies. Each sample thread was coded using five THEMES identified through analyzing the threads: Cooking (C), Administration (A), Career development (D), General information (G), and Social cue (S). Among them, more practice-related themes (e.g., C, A, and D) were focused in this study. In addition, the levels of MEMBERSHIP, which are technically assigned by the administrator of the OC according to the number of postings, were considered when reviewing initial messages of sample threads: New member (less than 10 postings), Member (10-100 postings), and Senior member (more than 100 postings).

Different purposeful sub-samples were consequently selected within the sample discussion transcripts (227 threads). The threads were divided into three groups according to the size of thread (i.e., number of replies): Small (0-2 replies), Medium (i.e., 3-16 replies), and Large (i.e., 17 replies and more). In this study, we assumed that each size group shows different interaction patterns and hence presents different aspects of interpersonal processes: (a) *small-size group*: why do the threads die?; (b) *medium-size group*: as the majority of the threads, what might account for the sustained task-relevant interactions in these threads?; and (c) *large-size group*: what circumstances foster the growth of these threads? Based on these assumptions, sample threads were selected from the three size groups. The sample threads selected from each size group were analyzed in terms of *WHO* (i.e., members: who replied to whom), *HOW* (i.e., process: conversational aspects), and *WHAT* (i.e., contents: what did they talk about). The contents were specified into three aspects: topics of contents (i.e., Task content, Task coordination, and Non-task), cognitive aspects (i.e., what kinds of information and knowledge they share), and concepts. Based on the results of the analyses, each sub-sample thread was graphically represented to show the complex components of interactions at a glance (see Figure 1).

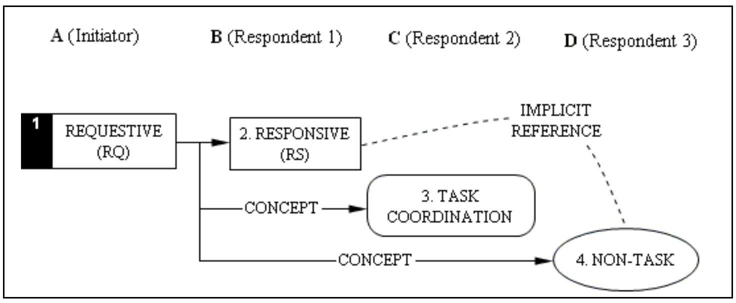

Figure 1. Components of interaction map.

Findings

Space limitation prevents us from providing detailed evidence, but we summarize the major findings and a forthcoming paper will provide additional details. From the results of analyses, we noticed that the initiator's role influenced the effectiveness of interaction processes. In this paper, hence, we briefly present general features of interaction and learning process and discuss further the roles of initiators and interaction patterns.

General Features of Interaction and Learning Process

The number of participants in each thread did not show any relationship with the number of messages in terms of themes and levels of memberships. Though the majority of participants were senior members, a few messages were posted by member(s) or new member(s) in the threads. In addition, the senior members who participated in the threads were not limited to a few members, but included as many as 26 members. These results suggest that senior members' contributions are well distributed across the topics of threads.

Regarding the content topics, most messages dealt with *Task content* related to the domain themes, for example Cooking (C), Administration (A), and Career development (D). One thread related to *Task coordination* in relation to community activities, for example improper capitalization in messages. For the content labelled *Non-task*, some threads included social cues, such as personal thoughts, reactions, and questions which are not related to the task content and the task coordination. This kind of content was often found in the threads presenting more complex and continuous interactions to ensure that discussions progress smoothly.

With regard to the cognitive aspects, the initial messages of the sample threads (n=227) identified three types of discussions: Problem solving, Sharing tacit knowledge, and Sharing thoughts and insights. Each thread presented a dynamic process of interactions depending on issues raised in the thread regardless of the themes, the initiators, and the types of discussions. In addition, an initiator's request was followed by various kinds of responses: *Direct response, References, Personal practice and experience, Alternative concern for the issue*. Along with these features, we found some examples of argumentation between two or more members discussing different opinions over issues. It is interesting to note that the messages representing opinions diverging from the majority were posted by new members.

Roles of Initiators and Interaction Patterns

Interpersonal processes in the threads appeared differently depending on how the initiators engaged in the discussion activities. With regard to the initiators' roles, Hara, Bonk, and Angeli (2000), for example, applied "the starter-wrapper technique" as an instructional strategy for online conferencing. They assigned two roles to each student: (a) the role of *starter* "who initiated weekly discussion by asking questions" and (b) the role of *wrapper* "who summarized the discussion" (p. 6). Although there was no assigned role in this OC, the role of initiator appeared significant and seemed to be critical to increase the degree and the quality of interactions in threads. The types of initiator engagement that we identified in the threads were *Initiation, Follow-up, Second initiation, and Wrap-up*.

Along with an initiator's increased engagement, initial requests sometimes triggered additional requests and hence several issues were discussed within one thread rather than one issue kept up until the end. For example, first, an initiator started with one request and then raised a second more specific topic derived from some of the responses to the first request. This generated a second round of discussion and more participants were engaged in this thread. Second, a different issue with an initial request was posted in the middle of the thread and then the discussion resumed on the initial issue. Third, as the discussion progressed, the members offered responses about deeper aspects of the initial issue. These findings show that the initiators' active participation fostered other respondents' further participation and deeper discussion on the issues. Depending on the initiator's role, various interaction patterns (Fung, 2004) were identified in the sample thread maps, such as *Branching, Cyclic, Chained, and Complex interactions.*

The majority of the sub-sample threads presented the *branching interaction pattern*, which develops when each member offers a response to the initiator without interacting with other respondents. In these threads, different individual members expressed their own thoughts embedded in personal experiences and offering various perspectives on the issue. The simple branching interaction pattern is often presented when an initiator's role is limited to the initiation without further engagements.

Along with the branching interactions, four threads also showed the cyclical interactions pattern. The cyclical interaction pattern is often presented when the initiator actively interacts with each respondent through follow-up and constructively engages in the activities within his/her own thread through a second initiation and a wrap-up. Another type of cyclical patterns was observed when two other respondents interacted with each other, for example, in cases of argumentation.

One thread presented the *chained interaction pattern*, in which a participant expresses one's thoughts, ideas, and opinion by referring to what others have responded in the thread. Within this interaction process, though the initiator's role did not seem to be active, the issue initiated at first was developed by expressing agreement or disagreement on the previous message.

The *complex interaction patterns* demonstrated more dynamic and complex processes by combining two or more interaction patterns, such as cyclic, chained, and branching throughout the whole thread.

In sum, the sample threads presented diverse interaction patterns, such as cyclic, chained, branching, and complex interactions depending on the topics of the threads, suggesting that productive and effective interactions occur in this OC. The interaction pattern of a thread seems to be influenced by the degree of the initiator's engagement, that is how s/he engages actively in the activities occurring within the thread.

Discussion and Conclusion

The characteristics of interaction and learning processes at the interpersonal plane in this OC were identified as follows: First, an initiator's role is crucial to effective interaction processes. Most issues discussed in this OC are derived from individual practice rather than collective practice among members. Each member brings an issue that s/he encounters in his/her practice in order to solve the problem or to change and/or to share others' knowledge, experiences, ideas, and insights. Through the interactive, collective processes among the group, the individual member can change and develop his/her practice. Hence, the initiator should be an *active participant* in the thread and *decision maker* to determine what s/he will do in his/her practice in relation to the issue, based on others' responses. In other words, an initiator's role as a *wrapper* (Hara et al., 2000) is critical in this OC. In addition, the initiator's active engagement through follow-up to others' responses elicits the *cyclical interaction pattern*.

Second, subsequently, most threads are not deliberately trying to achieve one shared agreement or conclusion. Rather, it is still meaningful for members to share and collect various aspects of an issue from other members who have different backgrounds, experiences, knowledge, and insights. This process is represented as the *branching interaction pattern.* This interaction pattern can occur in an atmosphere of *mutual respect* where members accept the others' practices, thoughts, and insights rather than evaluate and criticize them. This kind of interaction pattern corresponds to *cumulative talk*, in which "speakers build positively but uncritically on what the other has said" (Wegerif & Mercer, 1997).

Third, argumentations in the threads often occur when a member expresses different opinions from the shared insights that have been agreed mutually and accepted implicitly as part of the culture in this OC. In most cases, new members bring new issues to the OC and this allows existing members to reify the values shared within the OC. The engagement of new members hence seems to be one factor affecting the evolution of the community.

Fourth, this kind of argumentation usually advances the understanding of each other's perspective and in some cases participants come to an agreement in a warm, respectful manner along with kind social cues. Such argumentation process between two or more members often characterizes the *cyclical interaction pattern*. In addition, the sequence of messages can correspond to *exploratory talk* (Barnes, 1976), in which "partners engage critically but constructively with each other's ideas … These may be challenged and counter-challenged, but challenges are justified and alternative hypotheses are offered" (Wegerif & Mercer, 1997).

Fifth, the roles of senior members are salient in the interpersonal plane. This OC involves a sufficient number of active senior members, making it possible to sustain productive and effective interactions and to provide multiple perspectives depending on the topics of threads. Senior members also play a leading role in maintaining a positive atmosphere in this OC.

Implications

This study advances our knowledge of analytical approaches, which are multi-layered analysis and interaction maps presenting complex components of interactions and learning in CSCL contexts. By applying these approaches, CSCL researchers are able to investigate interaction patterns in terms of not only quantitative frequencies but also qualitative features and to further understand the natures of each interaction pattern and its meanings in the CSCL contexts.

In addition, the findings of this study offer practical suggestions for instructional strategies which can facilitate interactions and learning in OCs. When designing participation frameworks for online discussions, instructors should emphasize the importance of initiators' roles in the pertinent discussion threads and clarify their roles such as follow-up, second (or further) initiation, and wrap-up. It would be also helpful for instructors to observe interaction patterns to monitor and diagnose learners' interaction and learning processes.

Endnotes

(1) The form of learning when a teacher has the authority to determine that people designated as requiring knowledge effectively learn a curriculum taken from a pre-established body of knowledge (Livingstone, 2001, p.3).

(2) The form of learning when learners opt to acquire further knowledge or skill by studying voluntarily with a teacher who assists their self-determined interests by using an organized curriculum, as is the case in many adult education courses and workshops (Livingstone, 2001, p.3).
(3) Any activity involving the pursuit of understanding, knowledge or skill which occurs without the presence of externally imposed curricular criteria (Livingstone, 2001, p.5)

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Inscriptions Becoming Representations

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Abstract: This paper analyzes the interaction of three students working on mathematics problems over several days in a virtual math team. Our analysis traces out how successful collaboration in a later session was contingent upon the work of prior sessions, and shows how representational practices are important aspects of these participants' mathematical problem solving. We trace the formation, transformation and refinement of one problem-solving practice—*problem decomposition*—and three representational practices—*inscribe first solve second, modulate perspective* and *visualize decomposition*. The analysis shows how inscriptions become representations for the group through a historical trajectory of negotiation. This result is of theoretical interest because it shows how the practices underlying group cognition are contingent upon not only the immediate situation but also the chronologically prior resources and associated practices.

Introduction

Accounts of meaning making practices are motivated by questions concerning how the work of collaboration gets done and how these processes are reflexively aligned to the technological and social environments in which they are enacted (Koschmann, Stahl, & Zemel, 2007; Koschmann et al., 2005; Stahl, 2007). Prior work has drawn attention to representational practice as an important line of inquiry (Enyedy, 2005; Kozma & Russell, 2005; Roth, 2003). We argue, as have others, that such practices are actively negotiated and deployed, and inherently contingent on multiple temporal, material, and social dimensions (Dwyer & Suthers, 2006; Medina & Suthers, 2008; Suthers, Dwyer, Medina, & Vatrapu, 2007). Tracing out the details of representational practices provides an opportunity to expand our understanding of the unique and rich qualities of joint interaction enabled by multimodal media. The first major concern of this paper is to understand the development and role of *representational practices* in a particular episode of students' problem solving.

There is a convincing body of work showing that learning, problem solving and other group accomplishments are contingent upon the situation (Garfinkel, 1967; Goodwin, 2000; Greeno, 2006; Lave & Wenger, 1991). The second major concern of this paper is to examine how this situated contingency reaches into the past at successively larger granularities. As Blumer tells us, "any instance of joint action, whether newly formed or long established, has necessarily arisen out of a background of previous actions of the participants" (Blumer, 1969, p. 20). This contingency extends back in time with the aid of *persistent inscriptions* and other cultural artifacts (Latour, 1990; Wertsch, 1998). Therefore, to understand the development of representational practices in a CSCL environment, we need to examine participants' prior work together, and attend particularly to how persistent inscriptions makes this prior work available as a subsequent resource.

In this paper, we analyze the work of students in the Virtual Math Teams (VMT) Spring Fest 2006. This data was provided to us by Gerry Stahl, and partially analyzed by Stahl (2007). Students convened online to work on algebra problems in four sessions. We chose to begin with a remarkable event in the third session. It begins when Aznx (a self-selected pseudonym) says, "*I think I have an interesting way to look at this problem*," and proceeds to describe an innovative representation of the problem at hand that enables its decomposition into mathematically simpler expressions. Aznx's partners seem to quickly understand what he is trying to do, and indeed another participant, Bwang, supplies the actual visualization of the problem representation, using color to distinguish the components of the decomposition. Is this an instance of a brilliant insight arising whole cloth from the mind of an individual? If so, how were the others able to appropriate it so quickly? Or is the insight a product of group cognition (Stahl, 2006)? If so, how did the group build on Aznx's comment without much apparent negotiation, quickly applying methods of problem representation and decomposition?

To begin to answer these questions, we looked back at prior sessions to identify how the insight expressed by Aznx and the group's handling of this insight was contingent upon prior interactions. We found that participants' actions in session 3 continued the development of prior *practices.* These practices were *jointly developed* in the interaction of group members and shared by those members. These practices were largely enacted as *representational practices*: methods for generating, manipulating and interpreting inscriptions that the group developed for handling a class of problems. This paper reports on the representational practices we identified, and the manner in which they were developed by participants and applied to generate the insights of session 3. It then returns to some of the theoretical issues raised above concerning the temporally extended and artifact-mediated situatedness of group cognition.

Background

Data for this analysis was drawn from the Virtual Math Teams (VMT) SpringFest 2006 project. The project involved three student teams (A, B, C) each consisting of three student participants and one moderator, all at different geographic locations. Our analysis focuses on the work of team B. During the course of the project each team convened in four separate sessions to work on algebraic geometry problems. The participants interacted using *ConcertChat* (Mühlpfordt & Wessner, 2005; see Figure 2 and Figure 3), a software environment consisting of a shared whiteboard and a chat tool with the capability of referencing the whiteboard in a linked approach to artifact-centered discussion (Suthers, 2001). They also used a wiki to post their solutions during and after each session. These wiki pages, the software log files and re-playable instances of the *ConcertChat* environment served as our data sources. The replayer provided a rich contextual view useful for understanding the participants' inscriptional work as it developed concurrently with the interaction in the chat tool. Screen images in this paper are from the replayer.

The analysis began with identification of an episode of interest, and then worked both backwards and forwards at two granularities (termed *global* and *local* for convenience of reference) to construct accounts of the participants' interaction and accomplishments. We began with the episode from session 4 analyzed in Stahl (2007). In this episode, participants reference certain inscriptions available in the whiteboard, construing them as representational resources for resolving the question at hand. At the *global granularity of analysis*, we searched backwards to find chronologically prior episodes in which these inscriptions or related inscriptions were constructed, in order to understand how they previously functioned as representations for the participants. We first identified the point where the development of the inscription in question had been completed, because this is where the inscription had reached the form in which it was available in future episodes. Then the temporal extent of the episode was defined by working back to where the construction and discussion of the inscription began as well as forward to the completion of discussion about the inscription. Chat interaction was as important as inscriptional activity in identifying and bounding relevant episodes, since participants' chat referenced, labeled and interpreted inscriptions in the whiteboard. This process of searching backwards for relevant prior episodes was repeated until we had identified a chain back to the first session.

Then, the *local granularity of analysis* worked forwards within each episode to construct an account of the interaction within the episode. (Local analysis was not applied to the episode already analyzed by Stahl, 2007). Analysis at this granularity was undertaken in a manner similar to Conversation Analysis (Heritage, 1995; Sacks, 1992) as it is applied in Computer Supported Collaborative Learning (e.g., Koschmann et al., 2005; Stahl, 2007), but attended to inscriptional acts as well as conversations in the chat tool. Discussions in the chat are often woven with inscriptional work in the whiteboard in a manner that distributes conversation across the two media (Suthers, 2006). A trace of the contributions made in each of these media at the level of speech and inscriptional acts provide a resource for understanding contingent interaction. Certain events within each segment were annotated to document relationships between individual acts. For example, we documented the introduction or reuse of inscriptional practices or linguistic references that demonstrate contingent relationships from one act to the next. During local analysis, the segment under consideration was sometimes expanded to encompass the episode of meaning-making relevant to the question at hand. Issues identified locally also facilitated further global analysis of relationships between episodic frames.

In summary, we worked backwards "globally" to identify prior episodes on which a given episode's accomplishments may have been contingent; and worked forwards "locally" within each episode to identify participants' methods of meaning-making with the resources available. The result is a trace of contingencies at two granularities that enables us to recognize patterns in the data and better understand collaborative interaction and its accomplishment in shared environments (Medina & Suthers, 2008; Suthers et al., 2007).

Analysis

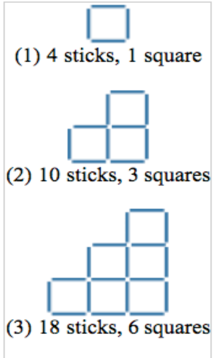
In the following three sub-sections we enumerate our observations of student interaction in the ConcertChat environment across three separate sessions. These descriptions will illustrate how inscriptional and discursive work emerge as joint representational practice in visual and linguistic media. In particular, we show that a movement from inscription to representation frames the emergence of practice in visual media.

For the remainder of the discussion we will refer to the three participants in Team B using their pseudonyms Aznx, Bwang, and Quicksilver. We will use transcripts and screenshots of the ConcertChat software to depict the work of the participants. Transcripts are based on the ConcertChat log file that includes all actions in the software, including whiteboard edits. To preserve space, we omit whiteboard edits from the logs, instead summarizing in the right hand column and providing figures as needed to display the resulting inscriptions. For example, lines 183-185 in Table 1 are whiteboard edits that led to the completion of an inscription shown in Figure 2. Also, we present only chat contributions that are directly relevant to our analysis: omissions from the chat are marked with double lines. See (Medina, Suthers, & Vatrapu, in press) for extended transcripts. Shaded rows in the transcripts identify lines referenced in our text.

Session 1: Initial Appearance of Practices

In this session participants are meeting to address their first task as part of the VMT SpringFest 2006 project. They are given instructions to derive a formula to determine the number of lines that make up a geometric figure at increasing values of *N* (Figure 1). After introductions and a brief discussion of the software the students begin working on the problem.

Bwang initiates the problem solving at transcript index [182] (refer to Table 1 and Figure 2 during this discussion) by posting, "you can divide the thing into two parts." He then begins to draw two sets of lines. One set is horizontal and the other vertical corresponding to the sample inscription in the instruction information (Figure 1). After completing this inscription, he proceeds to explain in the chat window how it can be expressed mathematically [219]. The other two participants take notice of both the inscription and the problem at [214] and [237]. Building on Bwang's initiative, the group begins to develop a formula for the growth pattern. Chat postings [237] through [348] show an exchange in which they are discussing the solution and propose two formulas [250] and [343]. The moderator inserts the formulas initially posted in the chat tool by Bwang into the whiteboard adjacent to Bwang's inscription [351]. After the transcript ends, the formulas are applied by the participants to complete the table as required by the problem instructions.



N	Sticks	Squares
1	4	1
2	10	3
3	18	6
4	?	?
5	?	?
6	?	?
...	...	...
N	?	?

Figure 1. Example given in instructions

Several practices that are taken up in latter sessions make their initial appearance in this episode. Bwang has brought forward two related (and time-honored) problem solving strategies. The first, which we call *decompose problem*, is exemplified by his recognition that the vertical and horizontal sticks (lines) composing the geometric figure can be separated into two equal sets, so that only one set need to be counted [182, 219]. The second, which we call *inscribe first*, *solve second*, is exemplified by his construction of an inscription before proposing an algebraic expression to generate the number of sticks [250] and squares [343]. This strategy is implied by the session instructions, but here the participants put it into action.

Bwang has also introduced a representational strategy, which we call *visualize decomposition*. His inscriptions visually decompose the structure of the geometric figure presented in the problem statement, spatially separating horizontal and vertical lines in a manner that reflects problem decomposition. By inscribing this in the whiteboard, Bwang has not only made a specific inscription available to the group, but has also displayed a strategy for visualizing problem decomposition. In subsequent sessions we will see how the persistence of the medium preserves and carries these resources forward to the future.

The three strategies are highly integrated in this episode: visualizing the decomposition in an inscription, as Bwang did, makes it easier to construct an algebraic expression. We will justify our identification of these strategies as *practices* by showing that they are taken up in later sessions. We will justify our identification of these as *three distinct* practices by showing that they are sometimes enacted in different ways

Table 1. Session 1 transcript

182	18:32:05	Bwang	you can divide the thing into two parts	
214	18:32:58	Quicksilver	what are the lines for?	Bwang has completed the inscription in the whiteboard (2)
219	18:33:05	Bwang	so you can see we only need to figur one out to get the total stick	
237	18:34:01	Aznx	Can we collaborate this answer even more?	
240	18:34:05	Aznx	To make it even simpler?	
244	18:34:15	Bwang	ok	
246	18:34:16	Aznx	Because I think we can.	
250	18:34:50	Bwang	((1+N)*N/2+N)*2	
292	18:36:31	Aznx	Aditya, you get this right?	
315	18:37:45	Quicksilver	What does the n represent?	
319	18:37:57	Bwang	the given	
322	18:37:58	Bwang	N	
326	18:38:02	Aznx	Yeah.	
330	18:38:05	Aznx	In the problem.	
341	18:38:37	Quicksilver	Oh	
343	18:38:38	Bwang	The number of squares is just (1+N)*N/2	
348	18:38:50	Quicksilver	We need that as well.	
351	18:38:52	Gerry	I put Bwang's formula on the whiteboard	

and combinations. For example, in this session *problem decomposition* is distinguished from *visualize decomposition* because the former is first expressed in language.

Session 2: The Practices Reappear in Different Forms

Moving now to the second day of the project, we find that the participants have decided to work on a problem of their own choosing. The previous day's inscriptions remain in the white board. Quicksilver takes the initiative and suggests working on generating a pattern for a pyramid [1379] (Table 2). The others agree on the idea [not shown], and Quicksilver then inscribes a pyramid shaped figure in the whiteboard (upper right of whiteboard, Figure 3). On completing the pyramid he references the figure from the chat posting [1415], explaining that it is a "side view" perspective. In the ensuing discussion, the participants attempt to show how the inscription can be decomposed in service of problem solving [1419-1473]. The references to the prior sessions' work [1419,1459,1466,1473] indicate that redeployment of prior accomplishments is a participants' concern. Our analytic approach of identifying contingencies to prior practices is aligned with this concern.

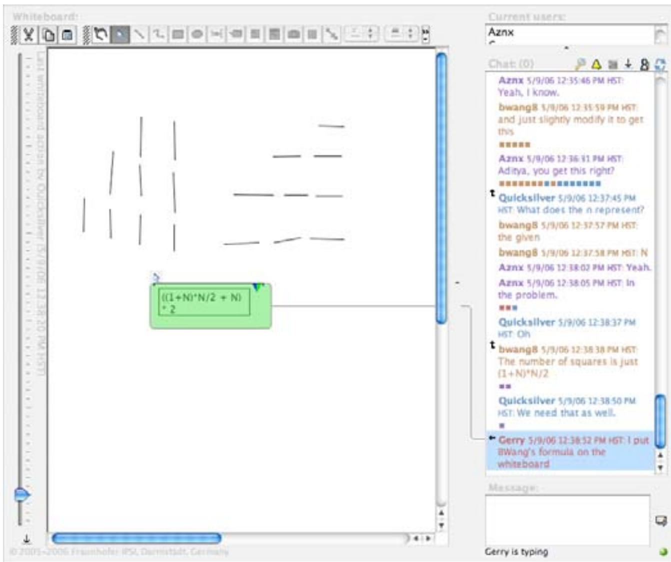


Figure 2. Initiating the practice of *visualize decomposition*

Further work is required to reach a shared understanding of the inscription as a problem solving representation. They are following an *inscribe first*, *solve second* strategy in service of *problem decomposition*, but this requires agreement on how the inscription functions as a visualization of this decomposition. Quicksilver indicates that the approach the others are discussing is not compatible with his "side view" [1493]. His inscription is nearly identical to the original figure provided in the instructional materials (Figure 1). However, his figure is offered as a representation of a three-dimensional pyramid, not a two-dimensional triangular form [1493; 1747-1756 (Table 3)]. The negotiation process takes place through joint manipulation of inscriptions as much as chat. Quicksilver restates his objective [1502] and, on Aznx's prompting [1509], proceeds to draw a second inscription (Figure 4a). He refers to this inscription as a "top view" [1543] because it shows a pyramid as viewed from above. Aznx assists by adding additional lines to the drawing to complete the decomposition visualization (Figure 4b). With the new inscription drawn from a different perspective, the participants begin a second round of discussion concerning the problem solution, with further joint construction and interpretation of inscriptions.

The "top view" inscription is further developed as a resource in another exchange between Quicksilver and Aznx [1659-1760, partially shown in Table 3]) as they attempt to work out a decomposition pattern. An emerging issue in their discussion is the dimensionality of the representation [1747-1760]. Aznx's question, "You want to do 3-D?" [1760], reveals that they had a different understanding of the role of the inscription for problem solving. Parallel to this discussion [1725 onwards], Quicksilver inscribes a third perspective using blue and red to distinguish different levels of the pyramid (see Figure 5). Quicksilver's response to Aznx's question is directed at Bwang at line [1765] in Table 3, requesting assistance in clarifying the group's activity. Bwang responds with a proposal to divide the layers of the pyramid into "levels" [1777].

In this episode, participants drew on their problem decomposition strategy from session 1 by deconstructing the pattern into components. Bwang proposes a decomposition strategy at line [1777] (Table 3) that is then reified as an inscription by Quicksilver in the whiteboard [1882]. Quicksilver enacted the strategy *visualize decomposition* using color rather than spatial separation to visualize the layers of the pyramid, showing that the strategy can be applied independently of its specific manifestations. The nested yellow, red, and blue squares in Figure 5 correlate to the top, middle, and bottom [1892] of the pyramid.

In attempting to clarify the representations by making several inscriptions, Quicksilver has introduced a new strategy, which we call *modulate perspective*. Beginning with the reference inscription so called "side view" (Table 2), he then inscribed three successive top view perspectives of a pyramid (Figure 4 and Figure 5). Color is appropriated both as a resource for problem-decomposition practice and as a representational tool to highlight the three-dimensional properties of the figure from a top view perspective

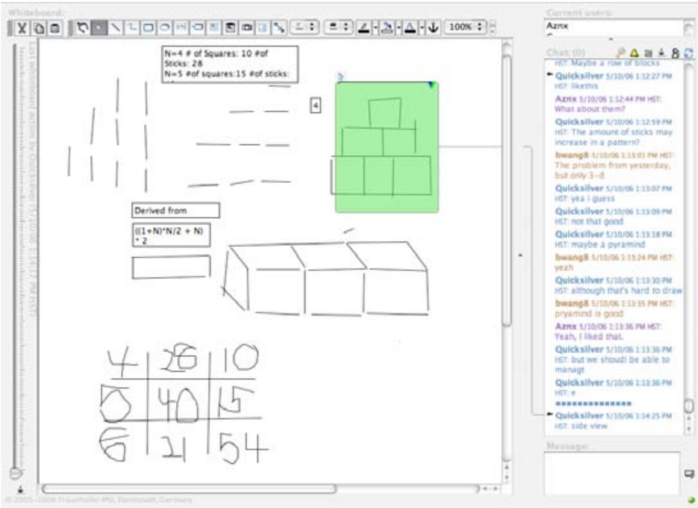
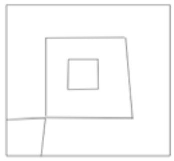
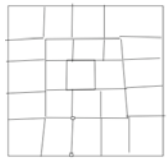


Figure 3. A “side view” of a pyramid is constructed and referenced (upper right of whiteboard)



(a) Top view constructed by Quicksilver



(b) Inscription in (a) extended by Aznx

Figure 4. "Top view" of pyramid

Table 2. Session 2

1379	19:13:18	Quicksilver	maybe a pyramind	
1415	19:14:25	Quicksilver	side view	Inscription complete (Figure 3)
1419	19:14:56	Bwang	isn't this the same as yesterday problem	
1423	19:15:03	Quicksilver	Really?	
1430	19:15:10	Aznx	Except it's 3-D.	
1433	19:15:12	Quicksilver	no it's three d	
1438	19:15:16	Bwang	ok	
1440	19:15:16	Aznx	So there would be more sticks	
1443	19:15:19	Aznx	and blocks	
1445	19:15:30	Quicksilver	and i was thinking of like 9 bricks on the bottom and 4 in the middle and 1 on top	
1450	19:16:45	Aznx	So, how should we approach this?	
1459	19:16:54	Aznx	What can we use that we already know?	
1462	19:16:57	Quicksilver	Layer by layer shown in a chart?	
1464	19:17:01	Bwang	well we can divide it into a front and a back	
1466	19:17:02	Aznx	I'd suggest yesterday's problem.	
1469	19:17:10	Bwang	yeah	
1473	19:17:22	Bwang	using the formula from yesterday's problem	
1493	19:18:13	Quicksilver	Oh!! Wait...Your thinking of the kind of pyramid that is flat on one whole edge	
1502	19:18:32	Quicksilver	I mean like a real pyramid that each layer is completely centered	
1509	19:18:44	Aznx	Draw it.	
1513	19:18:57	Quicksilver	i'll try	
1539	19:19:44	Bwang	o ic	
1543	19:19:49	Quicksilver	top view	
	19:21:36	Quicksilver		Inscription complete (Figure 4a)

The practices of *problem decomposition*, *inscribe first*, *solve second*, and *visualize decomposition* are sustained in this session. They are enacted in multiple cycles as the participants attempt to build on their previous work. Much of the group's work in this session seeks to coordinate the decomposition problem solving practice with the group practice of translating the inscriptions to algebraic formulas (Alterman, 2007). Aligning these practices is a joint accomplishment that allows the group to progress towards a solution. An inscription can support the decomposition practice only if participants recognize that inscription as meaningful in that way. Therefore it is not surprising that much group interaction is concerned with the utility of inscriptions for problem solving practices. In their joint manipulations of and negotiations about the inscriptions we are seeing *inscriptions becoming representations* for the group. In semiotic terms, the inscriptions are representations not by reference to fixed concepts, but by being in contextually defined relations to the situation at hand (Goodwin, 2003). The stability of these inscriptions as representations are derived from recurring practices associated with them, to be affirmed in the next session.

Table 3. Session 2

1725	19:25:04	Quicksilver	Well there's a problem	Begins to redraw inscription using color (Figure 5, bottom left)
1731	19:25:34	Aznx	So, the first one has 1 block.	Quicksilver completes blue and red, top view pyramid (Figure 5, bottom left)
1735	19:25:41	Aznx	and four sticks	
1739	19:25:48	Quicksilver	first block	
1741	19:25:51	Aznx	The second one has 5 blocks.	
1745	19:25:59	Aznx	Wait	
1747	19:26:00	Quicksilver	no it is 3	
1751	19:26:02	Quicksilver	d	
1753	19:26:03	Aznx	You're doing it wrong.	
1756	19:26:04	Quicksilver	3d	
1760	19:26:12	Aznx	You want to do 3-D?	
1765	19:26:27	Quicksilver	Bwang8, what are we doing?	
1767	19:26:30	bwang8	?	
1771	19:26:41	bwang8	you are trying to find a pattern	
1777	19:26:53	bwang8	divide them up into levels	
1824	19:28:07	Quicksilver	yeah	Quicksilver begins drawing yellow, red, blue inscription (Figure 5)
1831	19:28:28	bwang8	so we will just have to figure out how many sticks make up 3 by 3 blocks	
1839	19:29:06	Aznx	Yes.	
1843	19:29:15	Aznx	After that, we go up to Nth step.	
1848	19:29:20	Quicksilver	Yes	
1867	19:30:07	bwang8	ok, how do we figure that out	
1871	19:30:17	bwang8	3*3 blocks	
1876	19:30:26	Quicksilver	Break it down	
1878	19:30:27	Aznx	I'd say look for a pattern.	
1882	19:30:33	Aznx	and yes, break it down.	Quicksilver completes yellow, red, blue inscription (Figure 5)
1886	19:30:40	Aznx	What other possible ways are there?	
1889	19:30:44	Aznx	That we know of?	
1892	19:30:52	bwang8	top, middle and bottom	

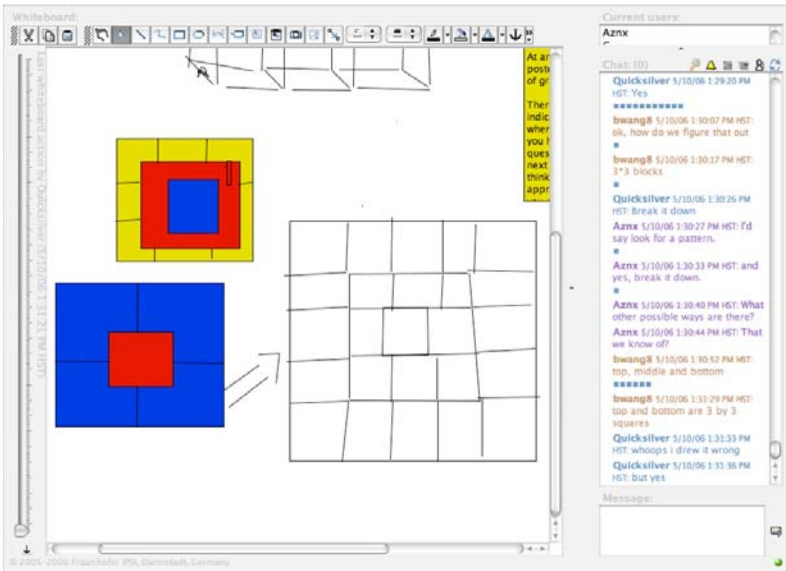
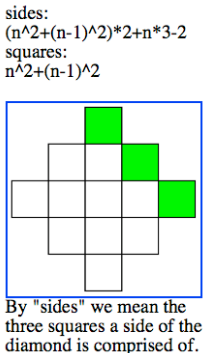


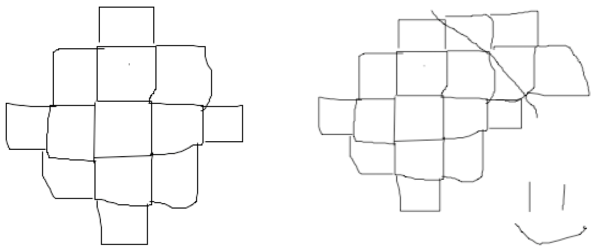
Figure 5. Color used to show layers of pyramid

Session 3: The Practices are Applied to a New Problem

This session represents a crucial point in the group's collaborative interaction in which they carry forward elements of their representational practices established in their prior work to a new problem. In the segment of work described next, Aznx initiates the *inscribe first*, *solve second* practice, producing an inscription that is then refined by Bwang, who appropriates color and perspective to display structural decomposition. This episode shows three of the prior practices being brought to bear, in some cases applied by different individuals or using different inscriptional devices.

Following a suggestion by the moderator to take up another team's solution in a different way, the participants begin working on deriving the equation for growing a diamond pattern. Team C posted their own work on this pattern and its equation on a wiki. Figure 6 shows the figure and formulas posted by Team C. Our team B participants view the wiki and begin to work out their own explanation of the pattern. At time 19:30:38, Aznx begins to inscribe Team C's figure into the whiteboard (Figure 7a). On finishing the inscription he begins reasoning about the pattern with Quicksilver [3911] (Table 4).





(a) as originally drawn (b) extended to show growth

Figure 6. Team C's wiki entry

Figure 7. Growth of a diamond pattern

Table 4. Session 3

3911	19:31:23	Aznx	How would you grow this pattern?	Aznx completes drawing, Figure 7a
3914	19:31:32	Aznx	Like a tesselation?	
3917	19:31:40	Quicksilver	No	
3920	19:31:45	Quicksilver	It doesn't tesselate	
3927	19:31:55	Aznx	Actually it does	
3932	19:31:58	Quicksilver	How?	
3936	19:32:03	Aznx	Hold on	
3950	19:32:11	Quicksilver	color the portion	Aznx draws diagonal line, Figure 7b.
3959	19:32:48	Quicksilver	Besides, It grows in all directions	
3971	19:33:16	Bwang	lets think about the equatin	
3974	19:33:22	Bwang	equation	
3977	19:33:23	Quicksilver	yes	
3980	19:33:30	Bwang	how did they derive it	
3984	19:33:50	Aznx	There's the formula	
3987	19:33:57	Bwang	(n^2+(n-1)^2)*2+n*3-2	
3991	19:34:08	Bwang	n^2+(n-1)^2	
3994	19:34:18	Aznx	The 3n has to do with the growing outer layer of the pattern I think.	
3996	19:34:23	Quicksilver	the sides and squares	
4000	19:34:55	Aznx	Right.	
4005	19:35:09	Aznx	There.	
4009	19:35:36	Aznx	I have an interesting way to look at this problem.	
4013	19:35:42	Quicksilver	Tell us	
4016	19:35:45	Aznx	Can you see how it fits inside a quare?	
4064	19:37:00	Aznx	Doi you guys get what I mean?	
4067	19:37:07	Bwang	yes	
4069	19:37:08	Quicksilver	Show what u mean on the witeboard	
4072	19:37:11	Quicksilver	i dont get it	
4075	19:37:14	Aznx	Bwang you show him	
4078	19:37:17	Aznx	since you get it	
4096	19:38:18	Bwang	we just have to find the whole square and minus the four corners	Bwang has completed the inscription in Figure 8 (bottom right).

In the ensuing exchange, Aznx argues that the pattern grows like a tessellation. Quicksilver requests explanation, and Aznx begins drawing additional squares on the top right corner of the diamond inscription (Figure 7b). Building on the joint practice of using color to distinguish elements of the representation Quicksilver [3950] suggests using color to indicate the "portion" of the diamond that grows. However, Aznx does not use color but indicates the portion with a line (Figure 7b). That this alternative visualization is taken as an appropriate way to meet the request evidences the group's orientation towards *visualize decomposition* as a practice independent of the particular means of visualization.

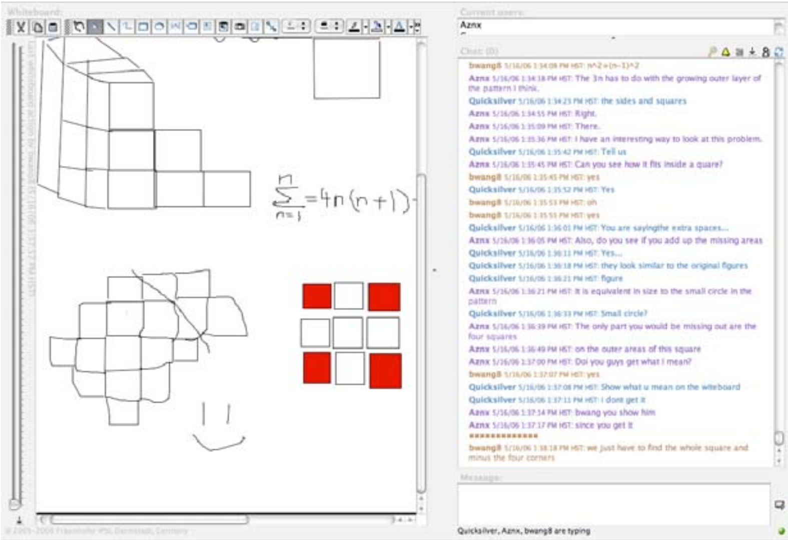


Figure 8. A square "minus the four corners"

As the interaction continues, Bwang initiates a transition to developing an equation for generating the growth of the diamond pattern [3971] (Table 4). Bwang copies Team C's equations into the chat window [3987 & 3991] and Aznx attempts to make sense of the formulas as Quicksilver attempts to translate this reasoning to the inscription [3996]. At this moment, Aznx provides an opener into an extended explanation of how the pattern can be derived by stating, "I have an interesting way to look at this problem" [4009]. Aznx elaborates on the potential solution [4016], noting that the diamond pattern is structurally decomposed from a square. Bwang indicates that he understands [4067], however Quicksilver is not as convinced [4072]. In response Bwang composes a new inscription (see Figure 8, bottom right), using color to show the corners of the square that are excluded from the diamond. It is a reification of the description Aznx contributed in the previous exchange but it also draws on previously shared representational practices of using color to show how the problem can be structurally decomposed. On completing the inscription, Bwang states the solution in simple terms [4096].

Summary

Across these sessions, we have seen how practices are enacted that build upon the prior interaction history of the participants. The participants applied their problem solving and representational practices as resources in addressing three different problems. For example, the practice of inscribing and then discussing a problem solution is a recurring pattern of interaction throughout the three sessions presented above. Further, for each of the above sessions, a different participant initiates this practice by first producing an inscription that the other two subsequently orient to through the chat discourse (Bwang in session 1, Quicksilver in session 2, and Aznx in session 3). The participants take up three representational practices consistently across the three sessions in support of the problem decomposition strategy. In session 2 and 3 we see that the practice of *inscribe first solve second* is iteratively enacted and composed with two additional practices – *modulate perspective* and *visualize decomposition*. In session 2, Quicksilver's use of color and perspective emerges into the joint work in support of both representational and problem solving practices. In session 3, Bwang's use of color to show a diamond decomposed from a square (Figure 8), draws on (1) a problem decomposition strategy that he originally introduced but that was given new manifestations by his partners, (2) Quicksilver's practice of using color to visualize decomposition, and (3) the prior practice of using drawings to reason about and structure algebraic formulas.

Discussion

Stahl (2007) defines "group cognition" as *"linguistic processes that can produce results that would be termed "cognitive" if achieved by an individual, but that in principle cannot be reduced to mental representations of an individual or of a sum of individuals."* The definition is similar to "distributed cognition" (Hutchins, 1995), although Hutchins emphasized distributed transformation and coordination of representations in service of well defined tasks, rather than linguistic processes in support of creative problem solving. Our account of representational practices includes both: linguistic acts and representational manipulations are tightly coordinated. According to Stahl's definition, any instance of distributed or group cognition is a process of interacting, so a group must interact each time it "cogitates" about a given problem. This is why we found the group's rapid uptake of Aznx's "interesting way of looking at this problem" remarkable. If one examines only the immediate interaction that follows, there is not enough work being done in the interaction to account for the complexity of problem solving being accomplished by the group. The analysis in this paper partially resolves this paradox by showing that group cognition doesn't take place in a situational vacuum. Members can draw on their prior interactions and on the products of those interactions as resources, and so need not work out their methods anew each time. That learners draw upon prior experience is well known, but microanalytic research in CSCL has tended to focus on the immediate situation. Our dual-level analysis demonstrates *how* the immediate intersubjective meaning-making of a group is contingent on prior episodes.

This perspective also sheds light on how the breakdown in session 4 analyzed by Stahl (2007) could have happened in a group that seemed to be functioning so well, and the manner in which it was resolved. Stahl alludes to facilitator's doubts that participants all understood what each other were doing. Although it was not our focus in this paper, we also see lack of convergence in the data reported here. It is conceivable for the group, "cogitating" in interaction, to produce the solution without any one person internalizing the entire solution procedure (or even fully comprehending the solution itself). Neither distributed nor group cognition is a capability of any one person. Therefore it is not surprising that in session 4 not everyone is prepared to explicate the solution. Faced with the task of accounting for their work they have to re-enact some of it (as detailed in Stahl, 2007). Their inscriptions are still available, and Stahl examines how their repair indexically invokes these inscriptions while also reconstructing them as representational resources.

Our analysis showed how this indexical and contingent nature of group accomplishments is temporally extended and is mediated by persistent inscriptions. These "immutable mobiles" (Latour, 1990) are powerful because they bring one moment's resources for interaction into another moment. The ability to re-establish mental representations can also play this role, but they are not accessible to either other participants or to us as analysts. In contrast, inscriptions that offer resources associated with prior practices are available to both participants and analysts. The reapplication of prior accomplishments was a participants' concern as well as our concern as analysts, and participants' inscriptions likewise served as a resource for our own work.

We showed that much of this group's work in mathematics involved not only constructing inscriptions but also negotiating interpretations of those inscriptions *as* representations. Three representational practices, *inscribe first solve second, visualize decomposition,* and *modulate perspective* bridged from the inscriptions to the problem solving strategy of *problem decomposition*. In coordinating these practices, the group works towards a shared understanding of the inscriptions as representations suitable for their task. Thus, the group's practices are representational practices in an essential way: the inscriptions are not intrinsically representations, but *become representations* through the negotiated practices of participants. Within each episode, inscriptions taken as representations provide not only indexical resources but also frameworks for immediate action (Streeck & Kallmeyer, 2001). On larger time scales, the persistence of inscriptions support the development of local solutions into recurring practices by serving as cultural artifacts for replicating and sometimes elaborating on those solutions (Wartofsky, 1979; Wertsch, 1998).

The analysis suggests that designers of collaborative learning environments make participants' prior inscriptional work available when relevant to subsequent sessions, and enable persistent inscriptions and conversational media to be used synergistically (Çakır, Zemel, & Stahl, in press). The data also illustrate the significance of enabling flexible expression through multimodal tools. The whiteboard enabled creative appropriations of the environment that could not have been "designed for," but were essential to the formative work through which participants constructed their own feature-rich *interface* for joint work. This suggests that our systems enable creative and unforeseen uses of inscriptional media (Dwyer & Suthers, 2006).

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Students Engaged in Collaborative Modeling

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Abstract: The chat communication between students engaged in a collaborative modeling task, using a system dynamics modeling approach, was analysed. The analysis revealed a pattern to how students begin new problems in a chat and the analysis of the objects of learning identified issues with both communication between students and the design of one of the tasks. We describe a number of the emerging interactional practices and draw conclusions regarding the instructional use of modeling problems.

Introduction

This paper presents an in-depth qualitative analysis of three online groups learning about a system dynamic concept. Despite sourcing the materials from a well-known, well-resourced group (Maryland Virtual High School, 2001; Verona, Ragan, Shaffer, & Trout, 2001), our previous analysis revealed that the three groups' online collaboration did not produce the necessary opportunities to achieve the anticipated learning outcomes (Reimann, Thompson, & Aditomo, Submitted 31/10/2008). In this paper, we use an in-depth analysis informed by conversation analysis to examine the groups' interactional dynamics. This analysis seeks to reveal how the students' organised their interaction to render it meaningful (i.e. their meaning making practices), with the hope of gaining some insights into why the students did not achieve the anticipated learning outcomes. Consequences for both the design of the activity and moderation of the collaborative online learning environment are then discussed.

Methods

Interaction analysis

In conducting this analysis, we followed the methodological recommendations of Heritage (2005) and ten Have (1999). One researcher (the second author) read the transcripts to gain preliminary observations about the overall organisational structure of the conversations. Data sessions were then held with the other authors, who had also read the transcripts, to discuss the initial observations. After examining the transcripts' overall organisation, subsequent analysis focused on particular segments which were seen as interesting for the current purpose/context. This was followed by more detailed turn-by-turn analysis of certain sequences of the conversation.

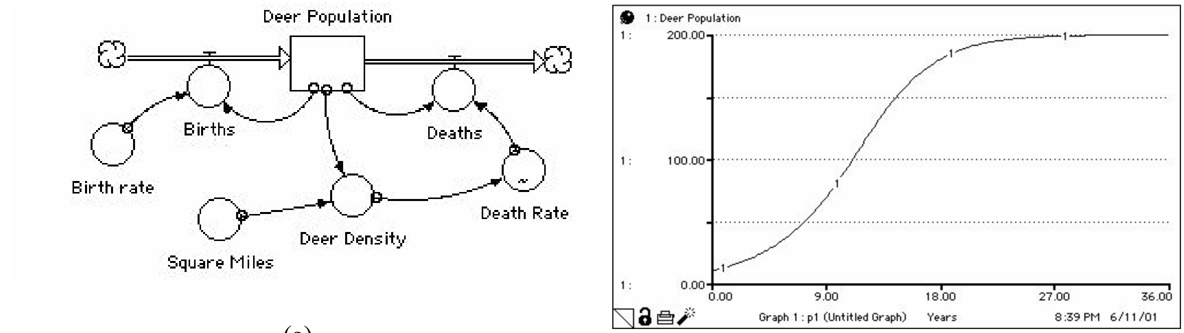
Participants and task context

Using a synchronous chat-based tool, three groups were given 15 minutes to collaboratively address three questions, posted in the chat environment, about a simple model of deer population in a certain habitat. These questions were:

1. This model includes a carrying capacity. What are the implications of this for the behaviour of the model?
2. Change the birth rate and death rate in order to find a combination that will result in a decline in the deer population despite unlimited habitat.
3. In real life, there is a limit to the size of the available habitat. Choose a size of the habitat. What kind of growth does this illustrate? What is the carrying capacity of your habitat?

Students were required to download this model an external website, which contained not only the relevant model, but also a web-based simulation about the same phenomena (why this is important will become clear later).

The collaborative task focused on the "S-shaped" behaviour or growth, which is a basic pattern typical of many complex systems (Sterman, 2000). This pattern is produced by a system dynamic model which includes a "carrying capacity" which sets a limit to the growth of a population. In the model examined by the students, the deer's death rate was formulated as a function of the habitat's density (i.e. the death rate increases as the habitat becomes more populated). When density was low, death rate was lower than birth rate, giving an exponential population growth. However, as the population and density rises, the death rate also rises, which slows the population growth. When density reaches a certain point, the death rate will be equal to the birth rate and hence the population will stop growing or stabilises.



(a) (b)

Figure 1: (a) The deer population model with a carrying capacity; (b) The S-shaped behaviour or growth pattern resulting from the model.

The task, in short, aims to help the students understand the relationship between the model structure (one which incorporates a carrying capacity) and the resulting behaviour or growth pattern (the S-shaped pattern).

Results

Overall structural organisation of the chats

Institutional interactions are often composed of certain phases which occur in a certain order (Heritage, 2005). (Casual conversations typically also have openings and endings, but what goes on in the middle are more unstructured compared to many institutional interactions.) Such overall structural organisation was also evident in the three groups' chat meetings, which exhibit roughly four phases:

1. Opening: Brief greetings
2. Establishment of interaction context: Remarks on group membership and/or tasks
3. Problem solving: Interaction addressing the problem or questions
4. Closing: Termination of chat meeting.

The purpose of outlining overall structural organisations is not to parse an interaction into discrete phases, or to demonstrate that those phases will occur in each interaction examined or that they will occur in a certain order. Rather, the purpose is to help analyse the activities that the participants were enacting through the interaction, and also how they oriented themselves towards this structural organisation (Heritage, 2005, p. 122).

The organisation of the problem solving phase

The analysis above has revealed the overall structural organisation of the chats. The analysis also shows how group members invoke aspects of their educational task or context to produce and structure their interaction. The problem solving phase will now be closely examined to determine how it is structurally organised.

The problem solving phase is structurally organised more or less along the questions which were posed by the tutor, although this is more evident in Groups 1 and 3, and less so in Group 2. That is, the group members discussed one question at a time, moving on when they had reached an answer perceived as adequate, or when someone invoked the time constraint as a reason to move on.

Table 1: An example from Group 1's discussion of the first question (Q1).

Chat line number	Chat content	Context of interaction
36	Stefan: i am back guys	
37	Marjory: me too	
38	Emma: me too. have been trying to write a note about my thoughts, but i can't get it to work.	
39	Stefan: so what we are supposed to do is to give a narritive explanation to the model,right?	Beginning of Group 1's discussion of Q1
40	Emma: This model includes carrying capacity, what are the implications of this for the behaviour of the model?	
Lines 41 to 71 omitted		

72	Emma: although the more shelter there is, the more the deer can hide. It's feasible that if there are too many deer, more will be killed as they can't hide from predators.	
73	Stefan: but the capicity is certain here	
74	Stefan: only related to the square	
75	Marjory: ok..why don't we move on to 2nd question?	Time constraints
76	Marjory: only 11 minuts left..	
77	Stefan: yes	End of Group 1's discussion of Q1
78	Stefan: Change the birth rate and death rate in order to find a combination that will result in a decline in the deer population despite unlimited habitat (hint - this means that sq. miles must be set to a REALLY LARGE value)	Beginning of Group 1's discussion of Q2

In the above (Table 1), Group 1's discussion of Q1 starts with line 39. This discussion was brought to an end by Marjory's reminder of their time limitation (Lines 75-76), to which Stefan conformed (Line 77). Stefan continued by posting a copy of Q2 (Line 78), effectively starting discussion of this second question. There was no objection to leaving Q1 and moving on to Q2, despite the unresolved difference between Emma and Stefan.

In Group 3, the discussion of Q1 started with Line 32 and ends with his Line 49 (Table 2). Different to Group 1, the discussion of Q1 in Group 3's chat was terminated not by reference to time constraints.

Table 2: Discussion of Question 1 in Group 3's chat.

Chat line number	Chat content	Context of interaction
30	Jane: i'll set the timer	
31	Ivan: I'm not sure what the first question mean. Are we surpposed to explain the model?	Discussion of Q1 begins here for Group 3
32	Jane: the first question means how does the carrying capacity of the area affect the model, i think	
33	Stewart: I think that is means the model needs to allow the deer numbers be raised so the environment can handle it	
34	Stewart: In farming terms we have a carry capacity of so many sheep per acre	
35	Jane: yes, so there must be a limit to the number of deers	
36	Ivan: If the density of deer is over the carrying capacity of the environment, then the death rate may rise?	
37	Stewart: So, if you have a carrying capacity of 5 sheep per acre ...	
38	Jane: yes because they wouldnt have enough food anymore	
39	Jane: or something...	
40	Stewart: Correct If your farm is 20 acres there your maximum number of sheep should not exceed what ?	
41	Jane: 100	
42	Ivan: 100	
43	Stewart: Correct	
44	Ivan: yes	
45	Jane: and then the death rate increases and birth rate decreases?	
46	Ivan: I think so.	
47	Ivan: then the density may go down to an appropriate level.	
48	Stewart: To keep the balance or carrying capacity correct I suppose	
49	Ivan: I think we've mad e the answer to the first question clear. Shall we go to Question 2	Discussion of Q1 ends here

In the interaction leading to the termination of Group 3's discussion of Q1, the group members built on each others' contributions to address Q1. In Line 45, Jane elaborated the group's previous discussion about the concept of “carrying capacity”. This elaboration was formulated as a question (about the consequence of reaching a system’s carrying capacity), thus demonstrating uncertainty and inviting an answer or correction. The other group members confirmed Jane’s answer and elaborated it further. This co-elaboration was apparently read as adequate for the purpose of the task, because none objected when Ivan announced that they had answered Q1 and proposed to move on to Q2.

Based on this observation of the organisation of the problem solving phase, we can see that the students’ overall orientation was towards an activity best described as “answering 3 questions in 15 minutes”. This is to say that the chats were not oriented towards other activities which were also possible, such as “discussing concepts or ideas about complex systems” or “understanding system dynamic models”. Had the chats been oriented towards these alternative activities, then we would expect to see the problem solving phases to be organised differently.

How questions are addressed/answered

Another interesting observation concerns how online groups address problems posed to them (see lines 31-33 in Table 2 above). Several observations can be made about Line 31, where Ivan proposed his interpretation of Q1. This line is composed of two parts, the first being prologue to the second, which contained Ivan’s proposal or interpretation of Q1. The modifier “I’m not sure …” in the first part conveys uncertainty and thus projects or anticipates possible rejection to the second part of this line (which was designed as a question, a further epistemic downgrading of this line). The first person inclusive pronoun (“Are we supposed to …”) indicates that this line addressed the group as a collective. Furthermore, by not specifying what is referred to by “the model”, this line treats the group’s knowledge of “the model” as unproblematic, at least at this stage.

The next two lines can be read as responses to Ivan’s proposal. Again, in both lines “the model” was still treated as an unproblematic referent. In Line 32, Jane did not give an agreement to Ivan's question/proposal, but instead put forward her own proposal. Hence, this can be read as an indirect rejection of Ivan's proposal. It is interesting also that Jane ended her line with "…, I think". This modifies and epistemically downgrades her proposal, conveys uncertainty and projects possible rejection.

In Line 33, Stewart also proposed his own take on Q1, hence indirectly rejecting (or at least, not taking up or elaborating) Jane and Ivan's previous proposals. Compared to Ivan and Jane’s proposals, Stewart’s line here was not designed to convey the same degree of uncertainty. This reading is supported by the fact that Stewart, rather than waiting for a response from others, continued by elaborating his proposal:

Stewart’s Line 34 was formulated as presentation of information, and the information (that farms have carrying capacity) was stated as a matter of fact. Jane concurred in Line 35 (“yes”), and continued by elaborating the meaning of Stewart’s information to the deer population or model (“there must be a limit to the number of deers”).

In the next line (36), Ivan posed a question about the relationship between carrying capacity and specific components of the model (density and death rate). By bringing up a different topic, Ivan was treating Stewart's informative sequence about the carrying capacity concept as complete or unnecessary to be continued. However, in Line 37, Stewart did not respond to Ivan's question, but continued his previous information sequence (as indicated also by the conjunction “so” at the beginning of this sentence). Furthermore, the ellipsis (three dots) in Stewart’s line here signals an unfinished turn. In effect, at this point of the discussion, two simultaneous streams of conversation have appeared.

Jane, in Lines 38 and 39, answered Ivan's question (and not to Stewart). Jane’s answer was formulated as an elaborated confirmation (“yes because …”). This answer, however, also conveyed uncertainty, as indicated the modifier “or something”, which can be read as inviting further elaboration of the topic Ivan brought up (carrying capacity and death rate). Stewart, however, responded not with an elaboration of this, but with an evaluation ("correct") which effectively closes Ivan and Jane's exchange by incorporating it into his own informative sequence. Indeed, Stewart used the same turn to continue his informative sequence.

At this point, Stewart's informative sequence resembles what previous researchers call an IRE (initiation-response-evaluation) sequence typical of teacher centred classroom interaction. Thus, Stewart’s question in Line 40 was treated not as genuinely seeking information, but akin to a teacher’s “test” question. This can be seen from Jane and Ivan’s response (both giving Stewart the answer he wanted: “100” sheep). And Stewart closed this IRE sequence with a short evaluation in Line 43 (“Correct”).

With the completion of Stewart’s IRE sequence, in Line 45 Jane tries to link the discussion of carrying capacity (with the conjunction "and") to specific components of the model (death and birth rate). Ivan responds by elaborating his opinion on the consequence (of reaching carrying capacity) to the “density” (which is another component of the model not mentioned before). Interestingly, in Line 48, Stewart pulls the focus back to “carrying capacity”.

Thus, it seems that whereas Jane and Ivan focused on the relationship between carrying capacity and specific components of the model, Stewart focused solely on the carrying capacity concept. This difference in focus was resolved interactionally, but not acknowledged or brought into explicit discussion by the group.

Instead, the act of co-elaboration which involved all members was taken as an adequate response to Q1. So when Ivan made an assessment (that they had answered Q1), none objected.

Conclusions and discussion

The interactions were organised along the constraints imposed by the task description (educational context, three problems, and time limitations). This organisation of the interaction might reflect a "satisficing" approach, in which the students were merely satisfying the formal requirements of the task (addressing 3 questions, with less concern over achieving shared understanding of the topic/phenomenon). One interactional practice which was regularly used was that of "uncertainty display". This was used to start the discussion of a new problem (this was observed in all instances from all 3 groups). Uncertainty display was most commonly performed by formulating the initial turn (with regard to a question or problem posed by the task) as a question, which invites others to confirm or to propose their own interpretations on the problem.

The practical recommendations of this analysis concern both the facilitation of the online groups and the design of the task. The identification of the four phases around which students' discussions were based suggests that more time should be given to allow enough time to complete the important problem-solving phase. This suggestion is supported by the time constraints that students used to decide that they should move on to the following question before completely understanding the first. As mentioned earlier in this paper, students did not attain the learning outcomes expected from this task. A combination of this analysis, with that examining the opportunities for learning (see (Reimann et al., Submitted 31/10/2008)) give some suggestions for the misunderstandings held by students. Further research needs to be conducted using similar analyses on a revised activity to determine whether these misconceptions about system dynamics models are due to the design of the task, or the difficulties identified by other authors in understanding this type of model (e.g. (Moxnes, 2004)). These initial results certainly suggest that the design of the task plays a large role in students' ability to understand these concepts.

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Collaborative Learning through Practices of Group Cognition

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Abstract: While there is evidence that collaborative learning consists largely of group-level practices, there has been little analysis and description of these processes as such; learning has generally been studied at the individual unit of analysis. Our research, in contrast, focuses on describing the interactional small-group practices that take place in learning contexts. This paper considers these practices and how they work together to form the foundation for effective collaborative learning activities. It analyzes collaborative learning activities in a paradigmatic CSCL setting to discuss such small-group practices as: resolving cognitive conflict, pursuing inquiry, maintaining a group problem space and coordinating multiple modes of reasoning. These have broad implications for foundational issues of temporality, indexicality and group cognition.

Individual and Group Learning

Learning has traditionally been considered a change in the knowledge of individual minds. More recently, it has been conceptualized at the opposite extreme in terms of participation in communities of practice (Lave & Wenger, 1991). In general, learning is conceptualized at the individual level and group knowledge building at the community level, despite evidence of the centrality of the small group, particularly in CSCL settings. An intermediate position between these two extremes is to consider how learning takes place in the practices of small groups (Stahl, 2006a). This is particularly appropriate for CSCL contexts, which are designed to support the building of knowledge in small groups and where learning is promoted through the effective interaction of students in online small groups.

Recent work in CSCL and the learning sciences indicates that learning takes place differently in small groups than when students are working on their own (e.g., Barron, 2003; Cohen et al., 2002; Schwartz, 1995). That is, if one measures individual learning as a difference between knowledge before and after some intervention, the inclusion of group work as part of the intervention makes a difference. These studies speculate that the difference is due to group processes, such as the practices involved in making ideas or concepts explicit and explaining them to group members. However, these studies were not specifically designed to capture the group processes and to describe how they were involved in group learning. Unfortunately, studies of learning rarely focus on the small-group processes themselves as activities of knowledge building.

We have conducted a research project during the past five years to explore the group processes involved in learning activities in a paradigmatic CSCL environment: the Virtual Math Teams (VMT) Project at Drexel University. It is based on our theory of group cognition (Stahl, 2006a), which we are still elaborating as a basis for understanding core processes underlying CSCL theory, design and practice. Investigations in VMT are designed to explore group practices in online collaborative learning of mathematics. The supporting technology is instrumented to capture all the data needed to observe group phenomena rigorously. We focus our analysis on case studies—some quite brief, others extending across several chat sessions.

Our publications to date have presented focused aspects of this research or described specific practices that seem to be important for understanding collaborative learning. In more theoretical reflections on this, my contribution to the *CSCL2* book argued for "rediscovering the CSCL" that tends to be lost in research at the individual-student or isolated-utterance unit of analysis (Stahl, 2006a, Ch 10). At the CSCL 2002 conference, I proposed using interaction analysis to study group perspectives and collaborative knowledge building (Stahl, 2006a, Ch 11). My CSCL 2003 paper differentiated individual interpretation processes from the group meaning-making practices (Stahl, 2006a, Ch 16). For CSCL 2005, I asked, "Can collaborative groups think?" (Stahl, 2006a, Ch 19) and then at CSCL 2007 looked at the group meaning-making process in some detail (Stahl, 2009, Ch 26).

The VMT research team—along with nine other CSCL labs from around the world—has just published a number of VMT Project case studies of specific group practices (Stahl, 2009). We are now trying to synthesize our findings and—in this paper—to understand how collaborative learning takes place on the basis of computer-supported group practices. In particular, four recent case studies show mechanisms of group cognition: resolving differences of perspective or approach (Toledo, Zemel & Stahl, 2007), engaging in inquiry or questioning (Zhou, Zemel & Stahl, 2008), creating or maintaining a group problem space (Sarmiento & Stahl, 2008) and coordinating mathematical problem solving across multiple media for communication or reasoning (Çakir, Zemel & Stahl, 2009). Here we want to look at the implications of these practices for collaborative learning in our CSCL context. This paper brings together these four illustrative analyses of group practices to show how learning takes place at the small-group level. The question of how this gets individuated—or internalized into the minds or practices of the individual students in the groups—is beyond the scope of this paper and of the methodology of the VMT Project.

It is often assumed that case studies do not lead to generalizable findings of theoretical import. Although the following four sections each focus on specific cases of interaction, they should be understood within the contexts of the larger research effort. The four doctoral dissertations (Çakir, 2009; Sarmiento-Klapper, 2009; Toledo, in preparation; Zhou, 2009) from which these studies are excerpted not only each consider multiple similar cases in detail, but also distill in different ways what has been learned more generally from the VMT Project as a multi-year team-research effort. Our sense of group work informally synthesizes rather diverse data from many virtual math team experiences. The VMT data corpus includes well over a thousand student-hours of chat in 370 session logs, covering a broad array of different experimental contexts. Most of these chats involved K-12 students working on math topics in groups of 3 to 6. Some involved college students or researchers—occasionally with as many as a dozen participants typing in the same chat room. Students came from around the US, as well as some from Brazil, Singapore and Scotland. Some seemed to be mathematically gifted, but others were probably average and some were at risk. The technology for early VMT sessions consisted of familiar commercial chat systems; by 2005 a system with chat and a shared whiteboard integrated by graphical referencing was used; and in 2006 this was expanded to include a lobby, a tabbed interface and a wiki repository. The math topics evolved from typical algebra and geometry challenge problems from the Math Forum's Problem-of-the-Week (PoW) service to more open-ended topics like the grid world and patterns of sticks and squares.

For a variety of reasons, some of the chat logs are considered better data than others for analyzing the mechanisms of group cognition. In the spring and summer of 2004, an intensive effort was put into coding ten simple chat sessions (PoW-wows). The VMT Spring Fests in 2005 and 2006 brought student groups together for sequences of four hour-long sessions, providing a glimpse into longer-term development of group dynamics and group learning. The four case studies summarized here look at excerpts from teams in the VMT Spring Fest 2005 and 2006 data, as well as going back to an early PoW-wow to look at purely textual interaction. In each case, the specific, highly situated analysis presents a concrete instance of phenomena that are visible—in their rich variety and individuality—throughout the VMT data corpus. These case studies shed light on some of the most theoretically fundamental and elusive themes of CSCL, semiotics, information science and learning science. In particular, each of the four studies addresses a major issue that has been influential in the CSCL research literature. Taken as a whole, they significantly advance our understanding of the nature and mechanisms of group cognition, as will hopefully become clear by the end of this paper.

Case Study #1: Group-Cognitive Conflict

The fundamental theories of the learning sciences—going back to the classic texts of both Piaget and Vygotsky—claim that learning is stimulated by an optimal level of differences among conflicting perspectives on a topic. Modern versions of learning theory refer to this claim as "cognitive conflict"—in the socio-cognitive psychological tradition focused on individual cognition (Perret-Clermont & Schubauer-Leoni, 1981)—and as the "inter-animation of perspectives"—in the socio-cultural dialogical tradition focused on collaborative small-group interaction (Wegerif, 2007).

Neo-Piagetian varieties of CSCL, at least, locate the power of collaboration in the attempt to overcome conflicting perspectives, with their attendant psychological tensions. We prefer to deal with the inter-animation of perspectives—the notion that multiple views or approaches can be productive for creative knowledge building in collaborative groups—by looking to see how the alternative perspectives actually interact with each other in group problem-solving efforts. Our analysis illustrates how the eventual resolution of a difference in approach to a problem can drive the group to solve the problem in a way that none of the participants would have individually.

In *Group Cognition* (Stahl, 2006a, Ch. 21, esp. p. 454f), it was suggested that VMT chats were largely driven forward and sustained by "math proposal adjacency pairs." These are interactions in which one participant makes a proposal bid to the group for the group's work and this is accepted or rejected by another group member on behalf of the group. The studies of resolution of differences look into a more complicated scenario of this interaction: the resolution of differences between two or more math proposals—initiated by different individuals, operating from within contrasting perspectives on the group topic and entering into conflict with each other. The group may take up their conflict and work through it across a longer sequence of postings, rather than just quickly accepting or rejecting a proposal on its own. Such a group activity can drive the work of the group for a significant period of time. The group response to "cognitive conflict" and the subsequent inter-animation of different perspectives can drive learning at both the individual and group level, as it sustains the chat interaction. The result of the resolution of differences can be an expansion of the joint problem space; group participants build a richer shared understanding of the object of their collaborative undertaking.

While there is widespread agreement on the importance of resolving differences for stimulating learning, there has been little analysis to date of interactional mechanisms by which differences of approach to topics or problems are resolved in small groups. The exploration of such mechanisms requires new qualitative research. It is hard to explore scientifically the resolution of differences in the minds of individuals. However, the resolution of differences within small groups may be observable in traces of their communication and interaction. The VMT Project provides a naturalistic experimental environment that was designed and instrumented to capture the interactions of small groups of students faced with collaborative learning tasks.

Participants in the group problem-solving sessions we have studies engage in a number of activities such as framing the problem or problems, discussing and assessing approaches, executing these approaches and assessing their results as part of performing the activity described as a "problem-solving session." Whether the problem solving is done face-to-face or through computer-mediated communication, as long as there are multiple participants with their respective approaches, procedures and assessment methods, there will need to be some degree of negotiation. Negotiation, defined as "a discussion intended to produce agreement" is a key activity in most group problem solving.

Participants negotiate which approach to use, who is to participate in the unfolding of proffered approaches and in what order competing approaches are to be used. Participants also negotiate how solutions are to be assessed for adequacy and correctness. This interactional process of resolving differences drives the learning activity of the virtual math team by structuring the continuity of the discourse. Participants negotiate when there are competing proposals that appear in their problem-solving interaction. As proposals are advanced, they may be accepted, rejected or ignored. Acceptance is shown in an uptake of the resources offered by the proponent of the proposal. The participants use these resources in similar or compatible ways. Acceptance thus means that the participants build on each other's postings and co-construct their framing of the problem, crafting their solution or assessing the adequacy of their proffered solution. A new posting accepts what was proposed by a previous posting and tries to re-situate it in the new poster's perspective. In the end, the group solves its problem as a result of such back-and-forth motion across differences.

Alternatively, in the face of rejection, participants may adopt other strategies to change the allocation of participation. The spurned proponent may recycle the proposal or post an alternate message, which claims to have some idea that would shed light on the group activity. However, this alternate message would require the other participants to ask the rejected proponent to reveal the idea. If this ploy works, then a counter-proposal may arise and begin another cycle of exchanges. If a proposal is ignored, its proponent may decide to go along with the other proposal, or present a new proposal, or lurk.

These group practices may not appear different from negotiation in a face-to-face setting, since acceptance, rejection or indifference can be communicated through postings as well as through talk. However, in chat acceptance, rejection or indifference may not appear immediately after the proposals to which they would be paired if the interaction were face-to-face. This makes it possible for participants who would otherwise be in an impasse to select parts of a long series of related postings that they can append to their own postings to break an impasse and thereby produce agreement. Thus, in the episode from which the following lines were taken, we find Mario selectively appropriating the postings of Alice and including them in his own presentation, despite his on-going rejection of her approach (Toledo et al., 2007). Similarly, we find Alice using the labels instigated by Mario in making her own contrary claims regarding the reliability of labels. They are tasked with proving why a given geometric situation is impossible, and they propose conflicting approaches:

29	Mario	You name where the green line meets the base
30	Alice	B
31	Alice	I have an idea that might help us find whats wrong with the pic.
32	Mario	We could use good ol' Pythag thm to see what BV is
33	Alice	Lets not

Participants recognize agreement when they post tokens of agreement in reaction to other participant's postings. Prior to these displays of agreement, participants show that they are aware that there is some problem, that a solution has to be found, that the solution has to be implemented. The awareness of a problem is expressed in postings that supply additional resources to help frame the problem. For Mario, these additional resources are in the form of labels that eventually frame the problem as a type that can be solved using the Pythagorean theorem. For Alice, labeling is not as consequential. Mario proposes a solution, which is based on the application of the Pythagorean theorem while Alice proposes a different approach to finding a solution. Mario, in proposing the Pythagorean theorem, puts forward an approach that the participants are assumed to be familiar with, while Alice proposes her alternative approach based on details of the given problem description.

We also note that the participants try to negotiate the order in which varying approaches may be applied to the problem at hand. Both Mario and Alice try to get the other participants to apply their approaches first. Both of them work independently and refrain from criticizing each other's approaches until such time as either uses some resource produced by the other to advance their own approach. Thus, Alice uses the labeling "BV" that Mario first used to point out how he cannot produce a correct result with his approach. Mario, in return, uses this claim to proceed to a computation of BV, which then produces a result, which is not directly traceable to the use of the Pythagorean theorem but rather to a set of properties associated with equilateral triangles, octagons and hexagons.

If one conceives of the problem solving as the effort of individuals, then one would predict a strong likelihood that this session would have broken down. Two strong willed students brought incompatible approaches to the given task, and each vigorously resisted the approach of the other. However, through the group-interaction processes of negotiation, the differences were resolved in a productive way that led to a solution of the problem and a continuation of the interaction. The resolution of difference did not take place through a vote among preexisting personal opinions, compromise, bargaining or consensus, but through a subtle and selective building of each participant's proposals upon the up-take of the other participant's proposals. A shared framing of the problem—or a joint problem space—was co-constructed through the inter-animation of alternative perspectives on the problem. Through fine-grained analysis of the chat log, it was possible to characterize various interactional methods that were employed by the group to achieve a productive inter-animation.

The excerpt that was analyzed can be seen to have been driven forward by the interactive moves between participants, motivated by their different perspectives. From a methodological viewpoint, it is important to note that the driving force is not the individuals as agents, but the tension between them. The math solution does not arise directly from the mental representations of the individual students, but from the group effort to respond to the conflicting differences and from the interplay between the participants. Of course, the brains of each student were necessary to interpret the group meanings created in the interaction and to articulate the utterances that were posted in the chat in response to the on-going discourse, but the problem framing, the group problem space, the solution path, the meaning making all took place at the group level in the visible, persistent chat.

What can be said about learning in this case study? If we talk about the group learning—having followed a path to that solution and having arrived at an understanding of the solution of the problem—then we can say that the group learning was driven by the process of interactively resolving the differences of proposed approaches. If, further, we assume that the individual students learned something from the experience, we can say they did so by "individuating" the group lesson, making it their own and integrating it into their personal understanding, where it can serve as a set of resources for future mathematical discourses (including internal discourses of thought). Because the effort to resolve differences in the chat discourse kept both Alice and Mario focused on the proposals of the other, it is likely that they will each internalize something of their opponent's perspective. In this sense, their individual learning will be driven by the confrontation with a perspective that conflicted with their own. Experiences like these could lead to their ability to learn on their own by reading and even by thinking about perspectives that conflict with their own initial ideas. Thus, analysis of this case study seems to provide insight into grand theories of individual and collaborative learning through cognitive conflict and inter-animation of perspectives as driven by the resolution of differences.

Case Study #2: Questioning to Learn

The study of practices of group questioning investigates another driving force of collaboration. Rather than seeing a question posed in a chat as an outward expression of an individual's mental idea or of an individual's request for information, we look at the methods of formulating and taking up a bid at questioning to see how the meaning and function of the questioning are negotiated interactively. Questioning is seen to be a potentially complex group process, incorporating a wide variety of interactional methods. A question can be part of a math proposal adjacency pair, putting forward a tentative proposal or reacting to a proposal bid. Questioning within a group can extend across a much longer sequence of adjacency pairs, advancing (or not) the problem-solving trajectory of the group. This analysis of questioning as an interactional achievement of a group—as opposed to a query in an individual mind—signals an innovative interactional approach to information science, with its conceptualizations of knowledge and information seeking that often underlie CSCL theories.

In an online collaborative context like VMT chats, questions are often not simple, well-defined queries for pre-existing information, but should be understood as situated moves within the group dynamic of the problem-solving effort. The object of the questioning is itself an emergent property of the interaction, through which the meaning is successively interpreted, refined and converged upon by the details of how the question is built, read and responded to. Questioning can play an integral role in the social relations among the participants, either positioning individuals as more or less competent or else maintaining peer standings. Question/response interactions are key to pursuing group problem-solving strategies, building a joint problem space and sustaining the team discourse.

We start by asking how it is possible to sustain a productive peer relationship in an online group when the raising of questions often reveals and makes relevant differences among actors in expertise, talent, ability, knowledge or understanding. Pursuing this line of inquiry allows us to look into the mechanisms underlying peer-group interaction. When there are differences in competence, actors need to work out among themselves the social order and the organization of their interaction. We look at how differences are attended to by participants in a collaborative peer group as part of the mechanism by which a group of students collaborate and manage the organization of their participation in ongoing chat interaction around problem solving. In particular, we examine the ways members of a small group (a) introduce differences in situated competencies as interactionally relevant, (b) organize their interaction to attend to these differences and (c) effect repairs where possible or find ways to proceed where repair is ineffective.

There are many ways that differences in competency can be introduced as interactionally relevant. Posing a question is often one way of accomplishing this. For example, an actor can ask a question about what is going on, or indicate there is a problem of understanding, or the actor can show the need for assistance by taking a particular kind of "next step" in a sequentially unfolding set of actions, for instance. When a questioner asks certain kinds of questions, she constitutes and makes relevant differences in expertise, knowledge, etc. as a matter for the recipients to attend to. Thus, not only is the questioner asking a recipient about the matter at hand, she is also instantiating their relationship in terms of the organization of their participation in the interaction (e.g., as questioner and answerer). In examining our data of students' interaction in VMT chats, we have noticed that *question-response pairs* are frequently invoked for attending to differences in local expertise and competency. For instance, asking a question may imply that the addressee(s) are likely to be able to provide some information that the questioner does not know.

When actors put forward certain questions that do not address explicitly their standing as participants in the interaction, matters of difference in knowledge, understanding, expertise, etc., can be addressed in ways that preserve a peer relationship between questioner and respondent. When actors make the organization of participation explicit in the question-response construction as a matter to be addressed, then the nature of the relationships among interactants becomes a matter of concern that needs to be addressed. Issues of differences in knowledge, understanding or expertise are then made relevant in terms of the way those relationships are worked out. In the following excerpt (Zhou et al., 2008), Nish positions himself as potentially "stupid" sounding; this lessens the possibility that respondents will position him as being less competent and will simply provide the requested explanation. The respondents, 137 and Jason, respond with relevant resources, without putting themselves in a teacher role. However, in line 180 Jason makes explicit the difference in math competency level between Nish and the rest of the group, effectively excluding Nish from full participation in the group work.

175	Nish	hope this doesnt sound too stupid, but wuts a summation
177	137	The sum of all terms from a to b
178	Jason	http://en.wikipedia.org/wiki/Sigma_notation
180	Jason	don't worry Nish, you'll learn all about it next year

In analogy to our analysis of a "failed proposal" in our discussion of math proposal adjacency pairs (Stahl, 2006a, Ch. 21, esp. p. 454f), we contrasted a "breakdown" example of a question-response interaction to a successful case in an attempt to specify the characteristics of a "successful question." The analysis suggests the following characteristics, some of which bear resemblance to those for successful proposals:

(a) *A clear question structure that elicits a response.* Making a report of one's math competency (beginning of line 175) may indicate some problem of understanding, but not present a question of its own. It does not elicit a response from the group. A question on a math topic with a clear structure is more likely to elicit a response without interactional trouble.

(b) *Information on what is known by the questioner.* A question such as "*what's a summation?*" may be ambiguous as to what it is really asking for, as there are multiple possible readings of it. Providing information on what the questioner already knows can help rule out some possible readings of the question.

(c) *Right timing and interactional context within the sequence of interaction.* Posing a question irrelevant to the ongoing discussion takes the risk of interrupting the group and deviating from the topic; careful work is needed to build the context for the question; ignoring this risks failure.

(d) *Engagement in the group process.* Indication of being engaged in the group process is also helpful in that it contributes to enacting and maintaining the peer relationship. Failing to engage in the group process like Nish does during the response construction can be destructive to the peer relationship.

Question-response interactions are key to pursuing group problem-solving strategies, building a group problem space and sustaining the team discourse. Participants do not just pose questions as information-seeking or help-seeking moves by individuals. Question-response pairs also function at the small-group level as mechanisms for managing peer relationships and organizing participation. They can function to include—or exclude—a group member. They can play an integral role in the social relations among the participants, positioning individuals as more or less competent and maintaining or adjusting peer standings.

Case Study #3: Evolving the Joint Problem Space

In order to engage in shared work as a group, there must be a task to work on together—what activity theory refers to as the "object" of the group activity. This must be more than simply a statement of a problem that was given to the group, but needs to be worked out as a "problem space" to which the group can orient itself in an on-going and practical way. We looked at how a group establishes and maintains its "joint problem space" (Sarmiento & Stahl, 2008). Our study grew out of an attempt to understand how groups maintain their continuity of interaction across discontinuities. It extended our understanding of how a joint problem space is maintained by stressing the sequential and temporal aspects of "bridging" methods that are typically employed by virtual math teams to overcome discontinuities that threaten to disrupt their effort. We now see the joint problem space as integrating: (a) social aspects (which transform participants into "members" of the interactional group), (b) domain content concerns (such as the group's characterization of their problem to be solved) and (c) temporal relations (the past, present and future as they are constituted in the unfolding sequentiality of the group interaction). This joint problem space structures the work and discourse of the group, providing a shared understanding of the references and concerns that are expressed in utterances and behaviors of the individual group members. This analysis replaces the easily misunderstood metaphor of common ground with a richer construct.

Theories of collaborative learning have identified the central role of the joint problem space (JPS) in coordinating work and establishing intersubjective understanding (Teasley & Roschelle, 1993). The concept of problem space had its inception within the information-processing perspective as a characterization of individual problem-solving activity. It was then reformulated and extended within the learning sciences to include the social and domain dimensions. Based on a detailed analysis of sustained online collaborative problem-solving activity by a small group of students over multiple sessions, we propose that the theory of the joint problem space should now be further expanded. In addition to the dimensions of social relations and domain content, which are increasingly recognized in the learning sciences, we argue for the salience of the temporal dimension. Our analysis shows that the joint problem space is co-constructed at the group unit of analysis through the temporal and sequential orientation to inter-subjective meaning making.

The JPS can now be seen as a *socio-temporal-semantic field*, co-constructed through interactions such as collective remembering and providing the basis for shared understanding of meaning. Processes of group cognition both sustain and are sustained by the JPS. The JPS is seen as an interactional phenomenon at the small-group unit of analysis, rather than as a convergence of mental representations of individuals as is often understood within theories of cognitive change and common ground. That is, the JPS is established and maintained through the sequential relationship of interactions among group participants as they build upon past actions, current situations and future opportunities of their group activity. Individual mental representations are possible spin-offs of the JPS, rather than causes of it.

All of these resources—the knowledge artifacts used and referenced, the sequential organization of cases and the temporal markers of prior activity—are organized in different ways with relation to the participants in a temporal or sequential space. The concept of "deictic field" developed by Hanks (2005) seems especially useful to define the relationship between this new "space" and Barron's domain content and social relational spaces (Barron, 2003). Hanks describes the deictic field as composed first by "the positions of communicative agents relative to the participant frameworks they occupy," for example, who occupies the positions of speaker and addressee as well as other relevant positions. Second, the deictic field integrates "the positions occupied by objects of reference," and finally "the multiple dimensions whereby the former have access to the latter" (p. 193). From this perspective, participants in the following excerpt constitute, through interaction, the relevant relative dimensions whereby they are to manage the positioning of agents and relevant objects of reference. They collectively co-construct a field of spatio-temporal indexicality incorporating bridging across sessions to locate activities, events and resources.

144	mathis	letz start working on number 8
145	bob1	we already did that yesterday
146	qw	we did?
147	mathis	but we did it so that there was only right and down
148	bob1	i mean tuesday
149	mathis	i guess we will do it with left and up?
150	qw	It would be almost the same.

In the interaction excerpted here, the three dimensions are intimately intertwined or unified. Participation is managed so that people who were or were not present in the previous session could nevertheless be included in remembering the knowledge constructed then. The knowledge artifacts (paths, formulae, procedures for exploring patterns) of the past are situated in the present work. The temporal discontinuity between sessions is bridged and the sequentiality of the group work is organized within the newly elaborated deictic field that the group incorporated in their joint problem space.

In our analysis of interactions we have observed that the content and relational dimensions are, in fact, relevant to collaborative problem-solving teams. Moreover, in expanding the range of phenomena analyzed to include longitudinal interactions across discontinuities, we have also uncovered time and the sequential unfolding of interaction as a third relevant and important dimension of activity. The interactional field is constituted by the participants to include problem-related objects and communicative agents associated with a prior interaction, and in doing so they position themselves and those resources within specific participation frameworks. The content objects (e.g., knowledge artifacts) and the relations among people (e.g., social positioning) are located within a temporal field, which provides a context for situating past, present and future events, for pointing to the events as temporally structured and for ordering utterances in their sequential relationships. Our central claim is that this temporal/sequential dimension is as essential to understanding collaborative interactions as are the content and relational dimensions.

The theory of group cognition takes as one of its central principles the dialectical relationship between social interaction and the construction of meaning. Meaning is not viewed as pre-existing in the minds of individuals, but as something that is constituted in the discourse within the group (Stahl, 2006a, Ch. 16). Nor is the group viewed as pre-existing as a set of people, but as a functional unit that constitutes itself in the interaction of its members when they position themselves within their group activity. From this perspective, the social organization of action and the knowledge embedded in such action are emergent properties of moment-by-moment interactions among actors, and between actors and the objects and the activity systems in which they participate collectively. The content space and the relational space, in Barron's terms, are mutually constitutive from this perspective.

Group cognition theory offers a candidate description for how the dynamic process of building knowledge might intertwine the content and relational spaces: "Small groups are the engines of knowledge building. The knowing that groups build up in manifold forms is what becomes internalized by their members as individual learning and externalized in their communities as certifiable knowledge" (Stahl, 2006a, p. 16). Thus, small group interaction can play a pivotal mediating role in the interplay between individual cognition (and the relations among the individuals) and communities of practice (and the knowledge objects that they share). Time as the sequential organization of activity seems to be a resource and an aspect of interaction that plays a significant role in how communities, groups and individuals achieve knowledge through small-group interaction. We have caught a glimpse or two of how temporality is marked and sequentiality is established within the discourse of small groups in VMT.

In our analysis of how small groups "sustain" their group cognition while engaged in brief episodes of online mathematical problem solving, we alluded to two ways in which time might be an important element of individual episodes of problem-solving activity. On the one hand, the collaborative activity involved in solving a problem can be "spread across" hundreds of micro-level interactions. On the other hand, individuals might internalize or individualize the meaning co-constructed through interactions and "sustain" the group cognition by engaging in later individual or group work. In either case, groups are described as sustaining their social and intellectual work by "building longer sequences of math proposals, other adjacency pairs and a variety of interaction methods" (Stahl, 2006b, p. 85).

Our analysis of interactions that bridge gaps across sessions confirms and extends these findings by suggesting that in longitudinal interactions, temporal and sequential resources are central to constituting activity as continuous by constructing and maintaining a group problem space. Interaction is taken here in the full sense that ethnomethodologists give it, as the "ongoing, contingent co-production of a shared social/material world," which, as Suchman argues "cannot be stipulated in advance, but requires an autobiography, a presence and a projected future" (Suchman, 2003). We have just began the work of describing in detail the interactional group practices that allow teams to construct and manage this expanded problem "field" by interweaving content, relational and temporal aspects of interaction.

Case Study #4: Coordinating Visual, Narrative and Symbolic Reasoning

We now consider how work in the group problem space is conducted when the online environment combines textual postings and graphical drawing media, as in a VMT chat room with shared whiteboard. By looking closely at the practices a student group uses to coordinate chat postings with carefully choreographed inscriptions on the shared whiteboard, we see how deep understanding of math can be effectively promoted through the organization of visual, narrative and symbolic reasoning within group interaction. Although drawings, text and mathematical symbols build knowledge and convey meaning through very different semiotic systems, in VMT sessions they are tightly coordinated and mutually informing. Students new to the environment spontaneously develop and share methods of connecting and coordinating work in these media.

Mathematical insight is often first grounded in visual reasoning with concrete instances, where relationships can be seen and understood concretely. These insights can then be pointed out to others through narratives, which instruct them how to see in the group's shared way. In mathematics, symbolic expressions are effectively employed to articulate, formalize and generalize understandings of relationships, providing means for symbolic manipulations that lead to further conclusions and to different forms of comprehension. The math artifacts that emerge from group work that coordinates visual, narrative and symbolic reasoning are not simple objects, but concepts that can only be understood through the coordination of their multiple realizations in these different types of media. The coordination of group work in the three realms supports deep mathematical understanding (as opposed to rote learning) of individuals by fostering understanding of the multiple realizations of math artifacts. It also enriches the joint problem space of the group's effort by interconnecting the semantic relationships of the three realms within a shared network of meaning.

We recently investigated how a group of three upper-middle-school students put the features of an online environment with dual interaction spaces into use as they collaboratively worked on a math problem they themselves came up with (Çakir et al., 2009). Our analysis revealed several important insights regarding the affordances of systems with dual interaction spaces. First, we observed that the whiteboard can make visible to everyone the animated evolution of a geometric construction, displaying the *visual reasoning* process manifested in drawing actions. Second, whiteboard and chat contents differ in terms of *mutability* of their contents, due to the object-oriented design of the whiteboard, which allows modification and annotation of past contributions. Third, the media differ in terms of the *persistence* of their contents: whiteboard objects remain in the shared visual field until they are removed, whereas chat content gradually scrolls off as new postings are produced. Although contents of both spaces are persistently available for reference, due to linear progression of the chat window, chat postings are likely to refer to visually (and hence temporally) proximal chat messages and to graphical whiteboard objects. Finally, the whiteboard objects *index* a horizon of past and future activities as they serve as an interactional resource through the course of related episodes of chat discussion.

Our analysis of this team's joint work also revealed methods for the organization of collaborative work, through which group members co-construct mathematical meaning sedimented in semiotic objects distributed across the dual interaction spaces of the VMT environment. We observed that bringing relevant math artifacts referenced by indexical terms such as "hexagonal array" to other members' attention often requires a coordinated sequence of actions across the two interaction spaces. Participants use explicit and verbal references to guide each other about how a new contribution should be read in relation to prior contents. Indexical terms stated in chat referring to the visible production of shared objects are instrumental in the reification of those terms as meaningful mathematical objects for the participants. Verbal references to co-constructed graphical objects are often used as a resource to index complicated mathematical concepts in the process of co-constructing new concepts. Finally, different representational affordances of the dual interaction spaces allow groups to develop multiple realizations of the math artifacts to which they are oriented. Shared graphical inscriptions and chat postings are used together as semiotic resources in mutually elaborating ways. Methods of coordinating group interaction across the media spaces also interrelate the mathematical significances of the multiple realizations.

Overall, we observed that actions performed in both the chat and whiteboard interaction spaces constitute an evolving historical context for the joint work of the group. What gets done now informs the relevant actions to be performed next, and what was done previously can be reproduced/modified depending on the circumstances of the ongoing activity. As the interaction unfolds sequentially, the sense of previously posted whiteboard objects and chat statements may become evident and/or modified, as in this brief excerpt:

12	137	So do you want to first calculate the number of triangles in a hexagonal array?
13	Qwertyuiop	What's the shape of the array? a hexagon? [*Reference to line 12*]
14	137	Ya [*Reference to line 13*]
15	Qwertyuiop	ok….
16	Jason	wait-- can someone highlight the hexagonal array on the diagram? i don't really see what you mean...
17	Jason	Hmm.. okay
18	Qwertyuiop	Oops [*Reference to Whiteboard*]
19	Jason	so it has at least 6 triangles?
20	Jason	in this, for instance [*Reference to Whiteboard*]

Here the VMT environment's graphical referencing tool is used to coordinate chat postings with previous chat postings as well as with objects on the whiteboard. Through the sequential coordination of chat postings and whiteboard inscriptions, the group successfully solved their self-defined mathematical challenge, to find a formula for the number of small triangles in a hexagonal array of any given side-length. Their interaction was guided by a sequence of proposals and responses carried out textually in the chat medium. However, the sense of the terms and relationships narrated in the chat were largely instantiated, shared and investigated through observation of visible features of graphical inscriptions in the whiteboard medium. The mathematical object that was visually co-constructed in the whiteboard was named and described in words within the chat. Finally, a symbolic expression was developed by the group, grounded in the graphic that evolved in the whiteboard and discussed in the terminology that emerged in the chat. The symbolic mathematical result was then posted to the wiki, a third medium within the VMT environment. The wiki is intended for sharing group findings with other groups as part of a permanent archive of community knowledge building by virtual math teams.

Our case study demonstrates that it is possible to analyze how math problem solving—and presumably other learning achievements—can be carried out by small groups of students. The students can define and refine their own problems to pursue; they can invent their own methods of working; they can use unrestricted vocabulary; they can coordinate work in multiple media, taking advantage of different affordances. Careful attention to the sequentiality of references and responses is necessary to reveal *how* the group coordinated its work and how that work was driven by the reactions of the group members' interactions with each other. Only by focusing on the sequentiality of the interactions can one see how the visual, narrative and symbolic build on each other as well as how the actions of the individual students respond to each other to co-construct math objects, personal understanding, group agreement and mathematical results that cannot be attributed to any one individual, but which emerge from the interaction as complexly sequenced. This analysis illustrates a promising approach for CSCL research to investigate aspects of group cognition that are beyond the reach of quantitative methods that ignore the full sequentiality of their data.

In our case study, we have seen the establishment of an indexical ground of deictic references co-constructed by the group members as an underlying support for the creation and maintenance of their joint problem space. We have seen that nexus of references created interactionally as group members propose, question, repair, respond, illustrate, make visible, supply symbols, name, etc. In the VMT dual-media environment, the differential persistence, visibility and mutability of the media is consequential for the interaction. Group members develop methods of coordinating chat and drawing activities to combine visual and conceptual reasoning by the group and to co-construct and maintain an evolving shared indexical ground of their discourse.

During the 18 minute excerpt analyzed in this case study, three students construct a diagram of lines, triangles and hexagons, propose a math pattern problem, analyze the structure of their diagram and derive an algebraic formula to solve their problem. They do this by coordinating their whiteboard and chat activities in a synchronous online environment. Their accomplishment is precisely the kind of educational math experience recommended by mathematicians (Livingston, 2006; Lockhart, 2008; Moss & Beatty, 2006). It was not a mental achievement of an individual, but a group accomplishment carried out in computer-supported discourse. By analyzing the sequentiality and indexicality of their interactions we explicated several mechanisms of this group cognition by which the students coordinated the meaning of their discourse and maintained adequate reciprocity of understanding.

The coordination of visual and semiotic realizations of the mathematical objects that the students co-construct provides a grounding of the algebraic formulas the students jointly derive in the line drawings that they inspect visually together. As the students individualize this experience of group cognition, they can develop the deep understanding of mathematical phenomena that comes from seeing the connections among multiple realizations (Sfard, 2008). Our case study does not by any means predict that all students can accomplish similar results under specific conditions, but merely demonstrates that this is possible within a synchronous CSCL setting and that a fine-grained sequential analysis of interaction can study how the group accomplished it.

Group Cognition and Learning

As a research field, CSCL has been deeply influenced by the theories of Vygotsky (1930/1978). In particular, one can say that CSCL is inspired by his visionary insight that learning takes place originally inter-subjectively (in small groups), and may then be internalized as intra-subjective (individual) learning. To this view, CSCL adds the hope that networked computer technology can bring learners together in new ways to take advantage of the power of collaborative learning. In this paper, we have tried to indicate a way of analyzing group learning that was not available to Vygotsky and that has been too little pursued within CSCL to date. By observing the group practices through which small groups of learners accomplish problem solving and other tasks, we can begin to determine the mechanisms that make knowledge building possible at the small-group level. We can observe group practices with the requisite detail by recording interactions that take place in CSCL settings, where the complete context of interaction can be captured, logged and replayed for analysis. Then we can describe the kinds of interactions that take place in group-cognitive conflict, in group inquiry, in maintaining a group problem space or in coordinating group reasoning across multiple media. These group practices set the stage for individual learning by allowing groups to reach achievements that the group's members can take away as skills, resources or methods for their own learning. As Vygotsky noted, the mediations involved in internalization are complex—and we would add that they are hard to observe. However, to understand individual learning as a cultural and developmental process, it seems necessary—and quite possible—first to understand the practices of group cognition that underlie it. We may then find that the traditional conceptualizations of individual learning must be reworked on the model of the small-group practices.

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Grassroots open, online, calculus help forums

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Abstract: The emergence of free, open, online, help forums has transformed tutoring from a private and individual activity into a public and collective endeavor. These forums support asynchronous exchanges between individuals from around the world. Students visit these forums seeking help on specific queries from coursework and receive help from anonymous others. In contrast to help forums designed and supervised by educational researchers, these forums have a grassroots origin. This paper investigates one such calculus help forum for evidence that forum tutors are scaffolding students to contribute to the successful solution of the exercise they posted. An analysis of 200 exchanges on limit and related rates revealed the presence of effective guided problem solving (marked by leading questions and hints), albeit to a limited extent. This work points to the need for discovering ways to augment constructive interactions in popular help forums that have become part of the student learning experience.

Introduction

Traditionally, tutoring is conducted as a private activity between a single tutor-tutee pair or small group of students. However, on the Internet, tutoring can be conducted as a public activity that connects people who share an interest in a certain subject domain with students seeking help. Via open, online, help forums, students communicate with a network of others around the world, seeking help on specific questions regarding coursework wherever and whenever they arise. At the same time, these forums connect the "network of others," a group of people who have the time, experience, and willingness to work on mathematics with students and (in some cases) with one another. Many of the open, online help forums operate free of charge and are staffed by volunteer subject enthusiasts, educators, and advanced students.

Open, online help forums are websites where students can post course-related queries that are then visible to the public. These forums are "open" in the sense that participation is not limited to any particular course or institution; members of the general population are attracted to them by necessity and interest. People learn of the forums' existence, access the web sites, and then choose whether or not to join in the conversation, either by posting a question or voluntarily acting as tutors to anonymous others. Because the exchanges take place on public websites, asking and answering questions effectively takes place "in a fishbowl." What is the nature of the activity that is supported by adding this broader social dimension to tutoring?

Tutoring in asynchronous environments

The Vygotskian (1978) notion of learning through social and cognitive interaction with a more experienced peer in the context of a task that lies within the tutee's "zone of proximal development" (Topping, 1996) has made its mark on computer-supported learning environments. In particular, the affordances of the Internet have been harnessed to support asynchronous interactions between students learning mathematics and more advanced others. For example, The Math Forum is a premier interactive digital library that, amongst other activities, houses an online mentoring program (Problem of the Week) that supports scaffolded problem solving of non-routine word problems from mentor teachers (Renninger, Farra, & Feldman-Riordan, C., 2000; Renninger & Schumar, 1998). At this site, students can also submit their own questions (either curiosity- or assignment-based) and receive an answer via e-mail from a volunteer staff member (Ask Dr. Math). The 'doctors' in this program undergo a tenure process and are required to demonstrate proficiency in content knowledge as well as communication and diagnostic skills (Underwood et al., 2006).

In contrast to these environments that connect *significantly more experienced* others with students learning mathematics, forums supporting asynchronous discussions of routine (homework) exercises between *peers* have also been designed (Kortemeyer, 2006). This forum, that is connected to the online physics homework system LON-CAPA, allows students who are enrolled in the same course but who do not necessarily meet in face-to-face instruction to interact and help one another (anonymously) as they work on similar homework assignments, with occasional input from an instructor. LON-CAPA provides randomized computer-generated problem statements to students (different numbers, choices, graphs, images, parameters, etc.) so that the discussion threads reference different versions of the same exercise.

In addition to these *designed* online tutoring environments, there are a number of *grassroots* forums that have sprung up on the Web, presumably in answer to a global need for accessible and affordable help. These sites are generally supported through advertisements and are open to the general public. In many ways, they resemble a blend of the designed environments that have been crafted by educational researchers. Like The Math Forum, these forums allow students to submit and receive help on specific queries; like the LON-CAPA forum, some open forums allow any member to contribute to an ongoing thread. Unlike the Math Forum, in an open forum all contributions are publicly available (although private messaging may be permitted); unlike the LON-CAPA forum, members of the general public can participate in these open forums. FreeMathHelp.com, the open forum that is the focus of this paper, has the following characteristics: open to the general public, permits any member to contribute to an ongoing discussion, anonymous participation, student-initiated help-seeking on specific exercises from coursework, and all threads are publicly available and archived.

Is there any evidence of effective tutoring in the brief encounters within a natural and unsupervised forum community? One mark of effective tutoring that has been identified in both laboratory investigation and naturalistic observation encapsulates the notion of scaffolding and the tutee's zone of proximal development: Although the learner is involved in what is initially, for them, 'out of reach' problem solving, the tutor ensures that they play an active role in learning and that they contribute to the successful solution of problems (Rogoff, 1990). This indicator is also appropriate for the purpose of this investigation since students initiate dialogues in the grassroots forums precisely when they are seeking help from more experienced others 'out there' on exercises that are initially, for them, 'out of reach.'

Methods

Vocabulary

There is a vocabulary associated with asynchronous interaction in online environments that is used for this discussion of online tutoring. An Internet *forum* is a web application for holding discussions and posting user-generated content. The term "forum" is used to refer to the entire community as well as to any sub-forum dealing with a distinct topic. A *post(ing)* is a contribution or message that is published on the site, either to initiate a discussion or in response to another's contribution. The set of contributions pertaining to a single request for help constitute an *exchange* or *discussion*, sometimes referred to as a *topic* or *thread*. These threads are displayed on the entry webpage of the forum and designated by the subject header or title of the initial post.

Design

In order not to disrupt activity in the online forum in any way, a purely observational and non-intrusive methodology was adopted. A sample of 100 exchanges on the limit and 100 exchanges on related rates (both dating back from 4/29/08) was collected from the archives of the calculus homework help forum on the site, FreeMathHelp.com.

Site choice and description

The calculus forum at the FreeMathHelp.com site was selected from several existing open, online, calculus help forums because it has an extensive history (archives dating back to 2005), includes a search mechanism for locating exchanges by a keyword or phrase, and is active in terms of daily postings and membership.

FreeMathHelp.com is an advertisement-supported mathematics help portal established in 2002 by Ted Wilcox, then an enterprising high school junior. The site contains 10 homework help forums organized by subject area (ranging from arithmetic and pre-algebra to calculus and differential equations). The sole requirement for becoming a forum member is registration (which entails agreeing to abide by terms for permissible content and/or conduct, providing a username and e-mail address, and selecting a password). Forum members can initiate threads in a discussion forum (e.g. as students posting mathematics questions) and can respond to others' posts (e.g. as tutors providing help). Forum members also have access to user profiles that include self-volunteered information on occupation, residence, contact information, as well as statistics on discussion board activity.

Each forum has moderators assigned by the site administrator who may lock topics and move, delete, or edit postings. In addition, members can edit their own contributions after they have been posted: If this is done after the member has logged off of the forum, then a message is appended to the altered contribution: "Last edited by [member] on [date and time]; edited [number] times in total." If editing takes place while the member is still logged on to the forum, then there is no official evidence of the modification although the general practice is for the author to indicate that the contribution has been edited.

The prescribed etiquette for participation (or "netiquette," e.g., Shea, 1994) is located in a "sticky" that is the lead posting within each help forum. This covers administrative issues (e.g., posting to an appropriate category) and politeness (e.g., patience while waiting for response). In addition, there are three rules that specifically address the content and framing of posts: include problem context ("Post the complete text of the exercise"), show initial work ("Show all of your work [including intermediate steps that may contain errors]"), and attend to clarity ("Preview to edit your posts [to minimize errors]").

The computer window for constructing posts contains traditional icons for highlighting text (e.g. italics, boldface, underlining, and font size and color), inserting material (e.g. external links and images), and organizing text (e.g. forming lists). A large selection of graphic "emoticons" (faces) is available for expressing emotions and attitudes (such as  [Very Happy] and  [Confused]), and LaTeX, a document preparation system, is available for typesetting mathematical text and symbols.

Topic choice

Students enrolled in "introductory calculus" are exposed to a large number of topics from differential and integral calculus. Although the exact coverage of the syllabus will vary across programs and institutions, there is a large amount of overlap in the topics that are presented. Two such topics, that reflect the diversity of problem types characteristic of the subject domain, are the limit concept and related rates. Both topics are challenging to students (Cornu, 1991; Cottrill et al., 1996; Engelke-Infante, 2007; Martin, 2000; Tall, 1993).

Sample characteristics

FreeMathHelp.com features participant profiles that include information on occupation, location, and interests. Whereas many student participants do not provide this information, the participating tutors in the calculus forum are self-reportedly students, educators, professionals, and retired mathematics professors. The most frequent tutor participants are from the United States, although there are representatives from a variety of other countries as well. In this paper, most participants are referred to by their self-designated user names or "handles" (such as *ihatecalc* or *skeeter*). However, if a user name appeared to reveal a participant's real world identity (such as a surname), a pseudonym was assigned to respect anonymity and privacy.

Although some tutors and students post more frequently, numerous tutors and students frequent FreeMathHelp.com. The sample contained 100 related rates exchanges initiated by 65 different students, with responses from 18 different tutors and 100 limit exchanges initiated by 67 different students, with responses from 23 different tutors. There was some overlap in participants (both students and tutors) across the two mathematical topics: 17% of these students posted queries on both limits and related rates, and 63% of the tutors provided assistance for both topics.

Coding

In order to characterize forum tutoring dialogue patterns, each exchange was assigned a participation code that tracks the number of participants, the total number of contributions in the exchange and the sequence of participation. For example, a code of 1231 would be assigned to a thread with four postings containing contributions from 3 different participants: a student [1] posted a problem and then two different tutors [2 and 3, respectively] responded, followed by a final contribution by the student [1]. These codes permit one to catalogue exchanges that involve multiple conversational turns, multiple participants, and multiple contributions by a single participant (in particular, by the student who initiated the thread). In addition, although the participation codes are agnostic with respect to the quality of the contribution (e.g. mathematical accuracy and depth, and pedagogical sensitivity), the codes can be used to identify threads in which the student remained involved throughout the exchange, and are therefore candidates for exchanges in which the tutor(s) scaffolded a student in the construction of a solution to the exercise that the student brought to the table.

Results

Five percent of the exchanges contained a scaffolding dialogue between a forum member or members with more mathematical expertise and a student who wished to accomplish a task that they were unable to initially complete. These interactions were characterized by extended, back-and-forth conversations in which the student was focally positioned as a co-constructor of the problem solution. Instead of acting as a source or transmitter of information in these exchanges, the tutors appealed to resources available to the students and encouraged them to ponder the mathematics involved in the construction of the solution. This was often accomplished through the provision of hints, a tactic that is employed by expert tutors and has been documented in computer-mediated one-on-one tutoring episodes (Hume, Michael, Rovick, & Evens, 1996).

Example of effective tutoring

Table 1 contains an exchange on related rates in which a tutor, *skeeter*, led a student, *kimmy*, to discover an error in her constructed solution. Ironically, *kimmy* produced the correct *numerical* answer to the exercise in her initial post. However, *skeeter* detected a flaw in the accompanying chain of reasoning and posed a series of progressively more direct questions to lead *kimmy* to this realization.

Table 1: Outline of exchange with tutor guiding the construction of the solution.

Author & Time	Post	Interactive trajectory
kimmy at 4:48 pm	What about this question:	**kimmy** posts her solution to the problem and seeks

	A police cruiser, approaching a right-angled intersection from the north, is chasing a speeding car that has turned the corner and is now moving straight east. When the cruiser is 0.6 km north of the intersection, and the car is 0.8 km to the east, the police determine with radar that the distance between them and the car is increasing at 20km/h. If the cruiser is moving 60km/h at the instant of measurement, what is the speed of the car. My work: Let y be the police cruiser Let x be the car being chased Let r be the distance between them. y= 0.6 km dy/dt = 60 km/h x=0.8 km dx/dt = ? r = ? dr/dt = 20 km/r Solve for r r^2 = y^2 + x^2 r^2 = 0.6^2 + 0.8^2 r = 1 Differentiate 2r dr/dt = 2y dy/dt + 2x dx/dt Sub everything in and get a value of 70 km/h for dx/dt	verification from a forum tutor
skeeter at 4:56 pm	your answer is correct, but I would like to know what **exactly** did you substitute in for dy/dt to determine dx/dt?	**skeeter** affirms the numerical answer but initiates a dialogue on the construction of the solution
kimmy at 4:58 pm	I substituted in 60 for dy/dt	**kimmy** responds to question from **skeeter**
skeeter at 5:05 pm	then dx/dt wouldn't work out to be 70 km/hr, would it? r dr/dt = y dy/dt + x dx/dt (1)(20) = (.6)(60) + (.8)(dx/dt) 20 = 36 + .8(dx/dt) 16 = .8(dx/dt_ 20 km/hr = dx/dt where is the mistake?	**skeeter** follows up on **kimmy**'s assertion, demonstrates its inconsistency, and positions **kimmy** to locate the source of the discrepancy
kimmy at 5:08 pm	My mistake or a mistake in the problem?	**kimmy** asks **skeeter** to provide more information
skeeter at 5:12 pm	your mistake.	**skeeter** locates the error as one that **kimmy** has made
kimmy at 5:12 pm	That wouldn't make sense, having a high speed car chaese, and the one being chased driving at 20 mi/h, now would it?	**kimmy** hypothesizes that the error is based on the problem situation
kimmy at 5:14 pm	I have no idea what I did wrong.	**kimmy** expresses inability to figure out the error
skeeter at 5:17 pm	why do you think I asked you about the value you used for dy/dt?	**skeeter** provides a more pointed hint that connects the

	what is actually happening to the distance "y" during the chase?	variable "y" with its referent in the form of questions for **kimmy**
kimmy at 5:31 pm	It is also decreasing! Ohh! That makes the 60 km/h a negative?	**kimmy** excitedly contributes the connection
skeeter at 5:37 pm	<u>correct on the negative</u> … note that the derivative itself is not decreasing, it's constant. Glad you figured that out yourself … now you'll remember it. 	**skeeter** carefully evaluates **kimmy**'s response to ensure mutual understanding and comments on **kimmy**'s active role in the construction
kimmy at 5:46 pm	Thanks a lot!	**kimmy** ends the exchange with appreciation

This exchange exemplifies how effective and exciting it can be for all involved when tutors in an online forum initiate student activity and participation through leading questions and hints. In this case, the result was an extended, back-and-forth conversation that culminated in the student discovering her initial flawed reasoning and that went well beyond an adjustment of a proposed solution. (The tutor could have simply informed the student that there was a sign error in her work.) Instead, with the help of the tutor and a channel of leading questions, the student was able to navigate a path to a valid solution.

Discussion

This glimpse of activity in a grassroots open, online help forum reveals how this environment can be a rich source of naturalistic tutoring episodes. There was evidence of forum members scaffolding others' problem solving and positioning students to participate actively in the construction of solutions. However, it is worth noting that these instances were not the norm. Discovering ways to increase the number of such interactions could improve the effectiveness of these popular forums and help students acquire the mathematical skills and techniques necessary to participate in disciplinary discourse.

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Understanding and Analyzing Chat in CSCL as Reading's Work

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Abstract: Synchronous communication using text chat—often combined with a shared whiteboard—is increasingly used in CSCL. This form of interaction and learning in small online groups of students presents novel challenges, both for the participating students and for researchers studying their work. Chats differ from talk-in-interaction since the composition, posting and visual inspection of text and graphical objects by any given actor is not observable by the other participants. These structural constraints on the organization of interaction require that actors deploy alternative procedures for achieving what turn taking achieves in talk-in-interaction. *This paper describes how communication is organized in text chat, where postings have to provide instructions on how they are to be read*. This organization is contrasted with turn taking in face-to-face communication. The notion of "reading's work" provides a guiding thread, which is explicated.

Introduction

Synchronous text chat seems to offer a particularly effective medium for joint learning activity, but it presents challenges for students using it because the group sense-making strategies to which they are accustomed in face-to-face interactions either do not work or work differently in the online setting, for reasons to be discussed. Similarly, sources of evidence normally available to educational researchers are not available from synchronous online interactions. Student groups develop methods of building their postings to convey instructions for how they are to be read. Chat researchers as well as chat participants must learn to pay heed to such instructions. As we will see, such instructions often involve the sequentiality of postings and the references among those postings (Sarmiento & Stahl, 2008).

We have explored the use of text chat for discussions of mathematics in small groups of students for the past six years in the Virtual Math Teams Project (VMT) (Stahl, 2009). Although we have reported on the technology design (Stahl, 2008) and on various case studies (e.g., Stahl, 2006; Zhou, Zemel & Stahl, 2007), this paper is our first attempt to describe the systematic workings of text chat, building on previous publications that began to clear the ground for this. We call this description a "simplest systematics" in analogy to the seminal paper on turn taking in talk by the pioneers of ethnomethodology and conversation analysis (Sacks, Schegloff & Jefferson, 1974), which we take as our inspiration.

Interacting Through Text Chat

In CSCL online chat systems like VMT, participants can engage with each other in a variety of ways. Rather than interact through emergent talk and observable embodied action, they: exchange text postings through chat technology, post text or graphic elements on a virtual whiteboard and/or use referential tools provided by the system.

Interaction in VMT involves actors using computer hardware and software in ways that allow for the production of shared, displayed representations or virtual objects possessing various features that allow these objects to serve as the means by which participants interact. Participants are represented in various ways in VMT in terms of various conventions and practices of action identification. These representations—i.e., naming conventions and displays, avatars, authored messages, posted graphical objects, etc., as well as various changes in the appearance of objects or the state of the system—provide documentary evidence of actor presence (Zhao, 2003) and engagement with the system. It is these same resources that are put to work to constitute social interaction among actors in a chat. In other words, *it is through the mediated exchange of what can be seen as locally relevant textual and graphical resources that chat participants organize and constitute their interaction*. The problem that chat participants face in task-directed chats of the sort we inspect is to coordinate their participation to collectively and collaboratively perform the task with the technical resources available in the hardware and software and with the textual and graphical resources they construct as relevant to their ongoing tasks. As it happens, this is a challenging problem that involves the management of and allocation of attention across multiple interface areas of the chat system and the ability to produce domain relevant artifacts (text messages, graphical artifacts, etc.) for inspection by others participating in the exchange of such artifacts.

Because these systems are designed in ways that allow participants to produce and inspect visual artifacts in particular ways, a natural question arises as to the nature of interaction that emerges in such environments. *How do these interactions differ from talk-in-interaction*? Speech exchange systems, like face-to-face conversation, telephony, video conferencing, etc., exploit and are constrained by the technical affordances of speech production. As Sacks, Schegloff & Jefferson (1974) described, speech exchange systems rely on the affordances of the technology of talk to organize social interaction. The sequential organization of face-to-face conversational speech exchange is a product of the fact that actors are co-present to each other in an embodied way, which necessitates taking turns at listening and speaking. Thus actors allocate opportunities to speak and to listen in various ways such that one speaker speaks at a time and they repair problems of intelligibility that arise from mishearings, poorly produced speech and overlapping speech.

Chat environments, on the other hand, are not speech-exchange systems at all, but rather systems of interaction that involve the display and inspection of visual artifacts, including texts (Garcia & Jacobs, 1999). The sequential organization of the production of visual artifacts is observable, available and documentable—and is something to which chat participants orient in their ongoing engagement in and through chat. However, the sequential organization of chat is not based on the same considerations that govern the sequential organization of talk-in-interaction (Garcia & Jacobs, 1999). One obvious difference is that overlap can happen in talk but cannot happen in most kinds of chat systems. Overlap is a phenomenon of talk in interaction. Problems of hearability, problems related to the allocation of turns in talk, problems that provide for repair in talk in interaction simply do not occur in chat. Different kinds of interesting troubles with respect to the intelligibility of postings can and do occur in chat, but these have to do with sequential placement of postings and other displayed graphical artifacts. It is because of this and other differences in the technical production possibilities afforded by chat systems that we feel compelled to provide the beginnings of a simplest systematics of online chat and to describe some of the ways that interactions through online chat differ from interactions through speech.

Co-Presence

The analysis we present involves consideration of a number of foundational features that are constitutive of social interaction. According to Goodwin (2000):

> The accomplishment of social action requires that not only the party producing an action, but also that others present, such as its addressee, be able to systematically recognize the shape and character of what is occurring. Without this it would be impossible for separate parties to recognize in common not only what is happening at the moment, but more crucially, what range of events are being projected as relevant nexts, such that an addressee can build not just another independent action, but instead a relevant coordinated next move to what someone else has just done. (p. 1491)

Not only must participants recognize what is happening, but participants must recognize "in common" what is happening. This notion strongly ties to Pollner's (1974) notion of mundane reasoning and Hanks' (2000) notion of indexical symmetry. Central to Goodwin's description are the practical achievements of presence, co-presence and the shared recognition of "what is occurring" in the scene. In other words, interaction arises when actors act in coordinated ways through mutual engagement with respect to recognizable and meaningful activities and shared-in-common and mutually recognizable orientations to (1) each other, (2) their actions and (3) features of the scene in which these activities are occurring. While Goodwin talks about coordinating contiguous actions as relevant to interaction, it is necessary to recognize that contiguity of action is not a requirement in all systems of social interaction.

In addition, social interaction requires more than reciprocal contact. Interaction requires *co-presence.* Co-presence is a condition of and for social interaction. According to Zhao (2003, p. 446), co-presence is "a form of human colocation in space-time that allows for instantaneous and reciprocal human contact." In ethnomethodological terms, co-presence is a gloss for the notion of a shared intersubjective world and the shared sense-making and reasoning practices by which shared inferential practices manifest and sustain the reality of that intersubjective world (Pollner, 1974). In short, social interaction requires reciprocity of perspectives founded in a common life-world that allows participants to act as though each is seeing what the other is seeing despite any differences in perspective that might arise (Pollner, 1974). According to Hanks (2000, p. 7), reciprocity of perspective is "neither similarity ('sharedness'), nor congruence per se, but the idea that interactants' perspectives are opposite, complimentary parts of a single whole, with each oriented to the other." It provides the basis by which an actor can reliably act as though other actors can, to some degree, see what she sees, know what she knows, feel what she feels, etc.

> The more interactants share, the more congruent, reciprocal and transposable their perspectives, the more symmetric is the interactive field. The greater the differences that divide them, the more asymmetric the field. (Hanks, 2000, p. 8).

This reciprocity of perspectives establishes a sense of co-presence in which the experiences and perceptions of the actors in a scene become practically available to each other. The practical problem for actors engaged in online chat is quite simply to figure out how to use the visual artifacts (virtual objects and text) and the affordances of the chat system so that they and others can recognize these artifacts and their use as constitutive of social interaction in that environment.

Interaction as Reading's Work

It is clear from the data we have inspected in the VMT Project that chat systems display an alternative organization of social interaction, one that is not based on the notions of consequential contiguity of action and turn taking in conversation. Specifically, in VMT actors may compose and post texts, develop and post graphical objects, etc., without being constrained by the actions of others precisely because the system allows it and because those actions are not witnessed or witnessable by other chat participants. In conversation, turn taking arises from just this notion that the witnessed and witnessable production of talk constrains the talk of others. The nature of these constraints is what organizes action into turns, turn sequences and the like. Thus turn taking requires that an actor and the recipients of that actor's actions collaborate to allocate their participation in orderly ways to produce meaningfully contiguous actions (Schegloff, 2007). Online chats often seem confusing and disorderly (Fuks, Pimentel & Pereira de Lucena, 2006; Herring, 1999) precisely because there is no obvious way to achieve the same kind of orderly contiguity as can be achieved in talk-in-interaction.

In practice, the achievable orderliness of online chat interactions is produced not by the way participants collaborate to produce actions, but by readers who, through the work of "reading," are responsible for identifying the progressively sequential nature of observable online postings even though the procedures of turn-taking in a strict sense cannot apply. One oft-heard complaint about chat is that postings are often "out of turn" (Garcia & Jacobs, 1999), which causes participants to struggle with the continuity or, as Schegloff (2007) calls it, the progressivity of ongoing interaction.

Contiguity does not operate in chats with the same manner as in talk-in-interaction. The actions participants perform to produce text or graphical objects for display and distribution to others are not observable or available to anyone but the person performing those actions. Anyone can post a text or a graphical object at any time without regard for the actions of others. This is a feature and affordance of common chat systems. Thus, any sense of progressivity and turn organization can only be achieved *ex post facto* as recipients' work of inspecting postings for how they could be constituted as a sequence of actions. Contiguity is problematic as a basis for establishing and recognizing the sequential organization of postings in chat. Consequently actors resort to other procedures and resources to achieve a sense of progressivity in their chats.

The constitution of sequentiality and the perceived orderliness of chat interaction is a reader's achievement in chat. The work required to make sense of textual and graphical postings is what Livingston terms *reading*. According to Livingston (1995), texts are built in ways that inform the reader how to read them. While Livingston's notion of reading is oriented to text-based materials, we would suggest that a more general notion of reading would involve the work of making sense of visual artifacts whether they are text-based, graphical, etc. Actors who are working to make sense of graphical or textual artifacts assume that these artifacts are produced, organized and displayed for inspection and to inform and instruct viewers concerning how they are to be understood. In other words, each visual artifact provides clues for how viewers are to make sense of it and, in the case of VMT, for how they are also to make sense of that artifact in relation to previously posted graphical artifacts and previous chat postings.

Interaction's Traces

The data we inspect for our analysis of social interaction in online chat consist of time-stamped chat logs of math problem solving in the VMT Project, where groups of three to five students in grades 6 to 11 collaborated online to solve math problems that required reflection and discussion. Each session lasted an hour and was supervised by a VMT facilitator who did not participate in problem-solving work with the other participants. The students understood that they were to collaboratively work together to produce solutions to posted math problems. This was made evident in the way that they managed their participation in the chats.

Various software platforms were used to facilitate these sessions, including AOL's Instant Messenger (AIM) and versions of a custom VMT chat environment. AIM provides a simple chat interface where the users interact with each other by exchanging short texts. These sessions were recorded as chat transcripts with participant identifier, the time-stamp of the posting and the content posted (see Log 1). Note how these postings use many textual features to guide the work of reading them (words, math symbols, chat abbreviations, capitalization, ideographic conventions, etc.); these guides are available in the log traces just as they were in the live postings.

Log 1.

1	pin (8:40:42 PM):	this is easy
2	pin (8:40:46 PM):	for the 12 triangle
3	pin (8:40:52 PM):	144=36+x
4	pin (8:40:55 PM):	so x =////
5	pin (8:40:58 PM):	....*
6	Avr (8:41:03 PM):	NOBODY DO THE MATH
7	Avr (8:41:06 PM):	I'M DOING IT

8	pin (8:41:12 PM):	square root 108
9	Avr (8:41:16 PM):	I KNOW I KNOW
10	Sup (8:41:19 PM):	lol
11	Avr (8:41:20 PM):	LET ME DO IT
12	pin (8:42:04 PM):	be my guest
13	Avr (8:42:39 PM):	okay

In contrast to AIM, the VMT environment provides two interactive components, namely a text-based chat and a shared whiteboard. One of the unique features of the VMT system is a referencing support mechanism that allows users to visually connect their chat postings either to previous chat postings or to areas on the whiteboard. VMT chat sessions are also recorded as transcripts with participant identifier, the time-stamp of the action performed and the content posted. Due to the added complexity of the whiteboard component and the referencing tool, VMT transcripts include additional types of actions, such as drawings, manipulation of an object on the board, messages indicating start/end of typing activity, referencing pointers.

In an effort to tackle the practical challenges of analyzing such complex transcripts we used the VMT Replayer tool, which allows us to replay a VMT session as it unfolded in real time based on the time-stamps of actions recorded in the log file. The order of actions we observe with the Replayer as researchers exactly matches the order of actions experienced by the users.

Technologically-Mediated Social Interaction

Interactants in chat work with chat technology as a form of technologically mediated social interaction. Technically (from the perspective of the network technology), interaction in chat-only systems is achieved as the posting of texts to the chat system for distribution to all the nodes logged into the chat server so that other participants have the opportunity to view the posted texts, read them and respond. For example, it is understood by users of chat systems that texts posted within a chat interface are made available to other participants and that other participants are to orient to these postings in their subsequently posted texts.

Even when a text is posted to which no one responds, the absence of a response may be a meaningful and consequential social action. For example, if a text is posted and no one responds, the lack of response may be treated as an accountable matter. Even if no account of a lack of response is called for, the posting and its subsequent treatment are social facts for the participants in the chat.

In chat systems with whiteboards, participants read and produce both text postings and graphical displays. Graphical artifacts posted to a whiteboard are available for other participants to view. Objects made available for inspection in the whiteboard are often treated as referential resources for and by participants in the chat. Participants in online chats with whiteboards constitute and treat each other as readers and authors of texts and graphical objects in their interactional work. (There are, of course, features of the interactional work that are oriented toward the management and use of the technology itself, which occur at individual terminals connected to the chat system and which are often times not available for inspection by other participants). The consequence of this for participants and observers of chat interactions is that the sequence, organization and textual resources of chat postings and the whiteboard positioning, manipulation and semiotic resources of graphical displays constitute the indexical ground (Hanks, 1992) by which the sense-making work of chat interaction is achieved.

Typically, different areas of the user interface are devoted to whiteboard activity and to chat. Participants are faced with the challenge of monitoring different areas of the interface while at times also producing text or graphical artifacts for posting and display. Participants appear to orient to the fact that simply posting a text message or a graphical artifact may not always be adequate to assure that other users will “see” it or give it the consideration that the author might hope for. Because a participant’s attention may not be given to that part of the interface displaying a newly posted text or graphical artifact, the producer of a text or graphical artifact cannot be sure that any given recipient is aware of a posted text or artifact unless an explicit response to that posting is produced and displayed. While graphical displays in the whiteboard are viewable by any participant, such displays need not necessarily be designed or produced to solicit responses from others, and they are typically not treated that way (although on occasion they are). Whiteboard items are often treated as displays to which participants orient in the production of chat messages. They are treated as illustrations of conceptual objects that are available for inspection, but they are not used specifically to elicit responses from viewers. Such responses are elicited through chat postings that make reference to these items. The whiteboard postings serve to provide indexical ground for chat postings. While user-generated text postings in the chat area are oriented to, produced and treated as a way of soliciting in-kind responses from others, whiteboard postings are typically oriented to, produced and treated as ways of establishing indexical symmetry (Hanks, 1996).

Thus there are significant differences between posted text messages and other graphical artifacts made available in VMT. These differences are significant because users of VMT themselves find the differences relevant and orient to these differences in their ongoing interaction. Furthermore, designers of CSCL chat systems recognize, orient to and display the significance of these differences in the way that these systems are designed. For example, in the VMT system, chat activities occur separately from the exchange or display of visual artifacts on the whiteboard. Different technologies are deployed to handle the exchange and display of graphical and textual artifacts. Furthermore, user interfaces (viz., chat and whiteboard) are designed to reflect these differences. Therefore, as we develop this analysis, we distinguish and demonstrate the relationship between two categories of visual artifacts, i.e., text postings (or messages) to the chat interface and graphical displays on the whiteboard.

The data we examine systematically demonstrate that text exchange through chat is used as the principle method of achieving "real-time" social interaction among participants. Progressivity and the appropriate projection and production of in-kind responses in chat serve as the basis by which participants come to treat their actions as social interaction. Indexical symmetry is an achievement of both chat and whiteboard activity. While text postings accumulate and scroll out of the visual field, whiteboard content is systematically used to establish indexical symmetry; relevant artifacts and occasionally emergent content are displayed for ongoing or persistent deictic reference over the course of ongoing chat interaction. In other words, whiteboard contents are items (1) which participants add and modify to display and share their then-current state of practical reasoning and/or indexical ground with respect to the task at hand and (2) to which participants refer in their ongoing chat interaction as persistent and recoverable demonstrations of practical reasoning and/or indexical ground.

Text Postings in Chat

Recent treatments of online chat interactions have documented that chats are significantly different from face-to-face interactions. 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 chat differs significantly from the way that turn taking, turn allocation and repair are performed in face-to-face interaction. The main difference is that *online chats are not speech-exchange systems*; rather *they are text-exchange systems*. It is no wonder that turn-taking organization and repair are very different phenomena than their counterparts in face-to-face interaction because the practical achievement of sequencing actions in chat is done so differently from speech by virtue of the technology of online chat. One consequence of this is, as Garcia and Jacobs (1999) point out, that the monitoring and posting of text messages are more loosely linked to the actions of other chat participants than the monitoring and execution of conversational actions among interlocutors in face-to-face interaction. Furthermore, where violations of projected next-turn actions are treated as repairable or accountable matters in face-to-face interaction, they are routinely treated as affordances of the technology by which online chats 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 & Golato, 2003).

Text postings in chat are designed to be read by all participants in the chat. Text messages differ from speech in a number of interactionally significant ways. In most chat systems, text messages are composed "in private," i.e., only the composer can witness its production, no other chat participants see the emergent text as it is being composed[1]. Chat participants only "see" a text after it is sent by its author. This process of text production and distribution presents participants with significant coordination concerns as they exchange texts.

One interactionally relevant consideration of online chat is that actors cannot closely coordinate with others by monitoring what others are doing since the actual production of chat artifacts (text messages, etc.) is unavailable for examination by recipients (Garcia & Jacobs, 1999). Problems of sequentiality and coherence become relevant to participants and are managed in the way that actors design their texts to be read and recipients come to read these texts. Therefore, *chat participants face the task of producing texts to be read in ways that are designed to display their sense and to read those texts in the ways they were designed to be read, even though the actual production of postings cannot be observed*.

In face-to-face interaction, actors rely on the sequential organization and production of talk, of embodied action, environmental resources, etc., for the achievement of interactional sense making. In online chat, participants only have access to posted texts, which typically do not display their sequential construction, the performance of self-repairs, etc. In addition, there are no technical constraints imposed on other actors when an actor composes a text. To illustrate what this means, consider the following. In speech exchange systems, when two parties speak at the same time, hearability of the speech of either party is compromised. When two parties compose and post messages at the same time, the readability of the texts is unaffected. Thus, there is no

[1] Some of the earlier chat tools offered interfaces that allow their users to witness the production of messages, such as Unix Talk and earlier versions of ICQ. However, such tools need to split the screen into multiple areas dedicated to each user so that the production process can be seen at all clients. This brings scalability and intelligibility issues of the chat taking place in the environment. Now most popular chat and IM systems employ the strategy of displaying awareness messages while the user is typing, and then display the message after the user posts the message to the server.

technical incentive to manage sequentiality in text-exchange systems as there is in speech-exchange systems. This doesn't mean that actors post willy-nilly in chats. Intelligibility is an issue with respect to how actors read the texts in relation to prior postings and in relation to whatever projected subsequent postings might be possibly relevant.

One example is shown in Log 2. At line 318, Avr's request, "*okay can you explain how you're getting it*," is presented in its entirety as a completed text. We don't see it's construction. This is contrasted with the work that Pin does in lines 319 to 323, 326 and 328, where he produces a sequence of short and grammatically linked postings that constitute, as a sequence, what readers treat as an extended posting.

Log 2.

318	Avr (9:00:52 PM):	okay can you explain how you're getting it
319	pin (9:01:29 PM):	im doing trial and error
320	pin (9:01:31 PM):	and i know
321	pin (9:01:32 PM):	that it is
322	pin (9:01:36 PM):	the sides
323	pin (9:01:39 PM):	are between
324	Avr (9:01:41 PM):	uh huh
325	Avr (9:01:45 PM):	I had a flash of brilliance
326	pin (9:01:48 PM):	21
327	Avr (9:01:48 PM):	just tell me the ratio
328	pin (9:01:50 PM):	and 21.5

While each of Pin's postings is presented in its entirety, they are constituent elements in what is being built to be read as an extended multi-post message. By using grammatical resources and short durations between postings, Pin is able to display in the texts he is posting that they are being presented to be read as a string of connected postings. In this way, users are occasionally able to approximate the display of the sequential construction of postings.

In Log 3, Lif organizes his response to Azn's query in multiple postings in such a way that the first two postings (lines 155 and 156) project the production of a longer elaboration on his findings regarding the problem at hand (line 161).

Log 3.

153	azn (8:18:27 PM):	did anyone get farther than this?
154	Ame (8:18:35 PM):	Because it never says which order the lengths of the segments are
155	lif (8:18:38 PM):	not really, all that i know is that
156	lif (8:18:39 PM):	:
157	Ame (8:18:39 PM):	we have to find out
158	Ame (8:19:00 PM):	I say there are six possible orders or length
159	Fir (8:19:00 PM):	well i said earlier that i just used trial and error and factored it out using the number I had picked and i found that it had to be less than 4
160	Ame (8:19:38 PM):	(n^2+4+4n)<9<(n^2+5n) is possible
161	lif (8:19:53 PM):	(n + 2)2 < 9 + n(n + 5) and 9 < (n + 2)2 + n(n + 5) and n(n + 5) < 9 + (n + 2)2

When a participant posts a text message, it may be constructed so as to be read as incomplete, projecting that a next post by that participant (not necessarily the next post in the sequence) is to be read as a continuation of the participant's current posting. This can be done using grammatical resources such as an incomplete phrase or sentence) and other lexical resources such as ellipsis or colons.

An increasingly available feature incorporated into chat systems is the production of "awareness messages," which are system-generated indications of activity performed by others. In the systems we examine (VMT and AIM), various awareness messages were available. When an actor engaged in the composition of a text message, a system-generated message was displayed to all participants indicating that the actor was typing. Even though the awareness messages indicate that an actor is typing, recipients cannot know what is being typed until the text is posted to the system. On occasion, actors type and apparently erase their typing without posting.

Chat repair is organized differently than repair in talk-in-interaction. Specifically, in order to effect a repair to a posted text, another text needs to be posted indicating that it is a repair and what it is repairing. This organization of repair arises because once a text is posted to the chat system, it cannot be manipulated any further. It becomes fixed even as it is displayed.

Log 4.

1	mcp (8:40:15 PM):	Oh, I see where your 18 and 10.125 are from now. I had already doubled and you waited till later. Yes, I'm with all this.
2	real (8:40:31 PM):	I got it
3	mcp (8:40:40 PM):	And dragging the sqrt(3) along would give exactly 156.
4	mcp (8:40:44 PM):	15
5	mcp (8:40:48 PM):	not 156

In Log 4, Mcp repairs his statement in line 3 by posting two more subsequent postings. In his first posting Mcp offers a new value (line 4). His next posting (line 5) establishes the relationship between the new value and the erroneous one he previously reported, and hence accomplishes the repair.

Another feature of text postings is that they are enduring in particular ways. Once a text is posted, it becomes part of the posting history and is accessible for review. It is possible to scroll backward in a chat to view previous postings. Once a text has been posted, it remains available for viewing in the history of the sequence of postings. This allows participants to examine previously posted texts that may have "scrolled" out of view over the course of their ongoing interaction.

The VMT chat system provides a referencing tool as an additional resource by which someone composing a text posting can link that posting to either a previously posted message or an object on the whiteboard. This tool provides actors with a graphical resource in designing their chat postings for linking the current posting to a prior one. Thus actors who compose texts and readers who read them need not only rely on lexical resources to indicate relationships between contiguous and non-contiguous postings.

The VMT referencing tool can also be used to link a current chat posting to an area of the whiteboard. It thus provides message designers with the means to make graphical indexical references in a manner that is somewhat analogous to the way gesture is occasionally deployed in face-to-face talk-in-interaction.

These are some of the features of text postings in chat. The interactional consequences of these features can be summarized as follows. By producing texts for display to other participants, actors are demonstrating their active presence by influencing and altering the state of the system by their actions. These very texts are not only produced to change the state of the system but are also produced to be read and to be responded to as meaningful by recipients. The meaningfulness of text postings derives from the work done by postings to establish a reciprocity of perspective between the text's author and its recipients. This is achieved using shared lexical, grammatical and textual resources and it is achieved by the exchange of postings that are treated as meaningful by participants. Thus *text exchange in chat provides for a form of social interaction based on the production and reading of posted texts*.

Graphical Artifacts

Graphical artifacts can be distinguished from text-based chat artifacts by virtue of the fact that:

- They are typically produced and displayed in a different part of the user interface than the chat system,
- They are designed for inspection by all participants but are rarely used to solicit text artifacts or other graphical artifacts from other participants and
- They call on recipients to make use of shared indexical ground and deictic practices different from those of chat for their intelligibility.

The work of producing graphical artifacts in the whiteboard involves designing and constructing artifacts to be seen and recognized in relation to ongoing chat postings and displayed whiteboard objects. This work, while similar to the work of producing for reading and reading text postings, displays certain particularities that derive from the technology of whiteboard artifact production. The technology of artifact production in the whiteboard of the VMT system involves the piece-wise production and arrangement of the constituent elements of the artifact. The piece-wise nature of artifact production allows recipients to witness the emergent achievement of the artifact on the whiteboard.

In addition, once posted, graphical artifacts on the whiteboard can be manipulated, altered, moved, etc. Actors can position or reposition one or a collection of such constituent elements in relation to other artifacts. They can also delete items from the current whiteboard space (though they remain available by scrolling back in the whiteboard history in the VMT system). This stands in marked contrast to text postings in the chat system that cannot be manipulated or altered in any way once a text is posted.

Another feature of the VMT system is that there are awareness markers that indicate user actions in the whiteboard. These appear in the chat window as a series of colored squares. A square appears in the chat every time an action is performed and posted in the whiteboard (see Figure 1). These squares are color-coded and correspond to the colors assigned to users.

The sense-making apparatus invoked by the placement and display of a whiteboard artifact involves recognizing what is presented in relation to other whiteboard artifacts and to ongoing chat activity. Whiteboard artifacts become relevant to actors in a variety of ways. One use of such artifacts is to serve as an illustration of a matter that is topically relevant in chat postings. Because these artifacts are both persistent and mutable, they can serve as indexical resources that provide for symmetrical perspectives on a matter under consideration in chat. As part of an ethnomethodological study of cognitive scientists' whiteboard use during design meetings in a face-to-face setting, Suchman conjectured that "…while the whiteboard comprises an unfolding setting for the work at hand, the items on the board also index an horizon of past and future activities" (1990, p. 317). In other words, what gets done now informs the relevant actions to be performed subsequently, and what was done previously could be reproduced or reused depending on the circumstances of the ongoing activity.

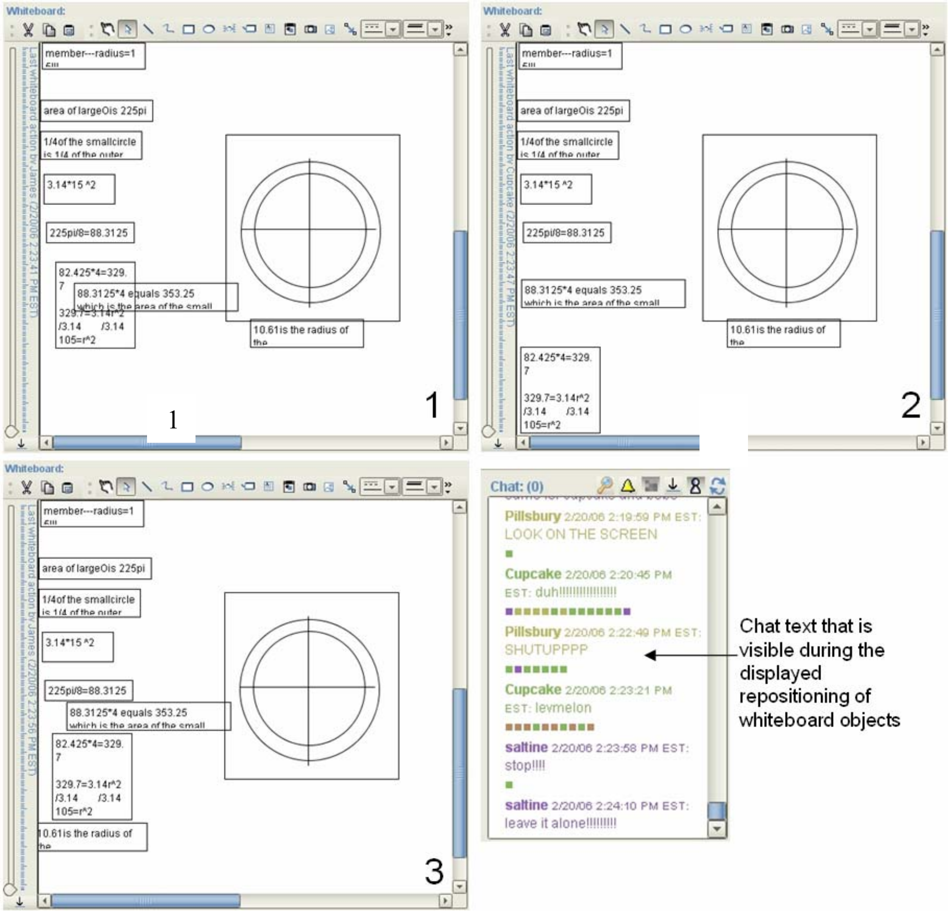

Figure 1. Movement of graphical objects to do practical reasoning.

Because of the mutable and persistent nature of whiteboard artifacts, it is possible for actors to add objects and arrange them. The production and placement of whiteboard artifacts allows an author to display to him/herself and other recipients the achievement of practical reasoning as the piece-wise construction of these artifacts. For instance, Figure 1 shows an example where the participants move a number of individual textboxes to achieve a particular layout on the shared space. The achieved organization displays how individual items are seen and read as related pieces of a larger organization.

Additionally, practical reasoning is demonstrated by the placement and juxtaposition of these artifacts as indexical resources relevant to the ongoing interactional work of the participants. Participants coordinate their chat activities with whiteboard artifacts and also coordinate whiteboard artifacts within the field of extant artifacts using the deictic resources of the technology (reference tools, linguistic deictics embedded in the chat, etc.) and the artifacts themselves as deictic resources. For instance, Figure 2 presents an example where a participant uses a recently completed drawing as a referential resource to formulate a question directed to his teammates: "*so it has at least 6 triangles? / In this, for instance*."

Chat postings and objects posted on the whiteboard differ in terms of the way they are used as referential resources by the participants. The content of the white board is persistently available for reference and manipulation, whereas the chat content is visually available for reference for a relatively shorter period of time. This is due to the linear growth of chat content which replaces previous messages with the most recent contributions at the bottom of the chat window. Although one can make explicit references to older postings by using the scroll-bar feature, the limited size of the chat window reinforces a referential locality between postings that are visually proximal to each other. This visual locality qualifies the whiteboard as the more persistent medium as an interactional resource, although both mediums technically offer a persistent record of their contents through their scrollable histories.

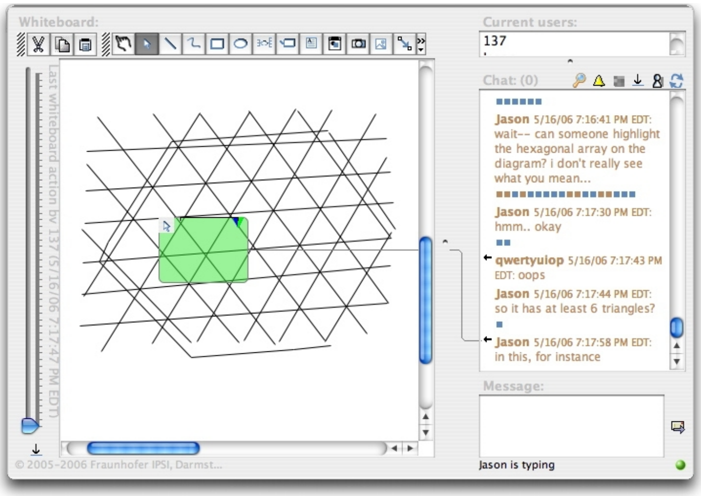

Figure 2. Jason indexes an area of the whiteboard.

A Systematics of Interaction in VMT

In this paper, we have described the systematic affordances of AIM and the VMT chat systems by which actors produce and inspect various kinds of locally relevant visual artifacts as the means by which they organize their online interaction. In synchronous computer-mediated communication systems such as these, actors produce an assortment of visual artifacts—textual and graphical—to achieve co-presence and establish indexical symmetry with respect to matters of relevant concern. The work that actors do when posting graphical and textual materials is the work of creating "readable" visual artifacts that allow recipients to achieve a sense of interaction by making sense of what they see in the chat system.

When it comes to talk, co-presence and the contiguity of actions provide for turn taking as the foundational organization of talk-in-interaction (Schegloff, 2007). In chat systems of the kind we have investigated, continguity is not a relevant or determining factor in assessing the meaning of an action. It is not about what just happened or what happens next. It is about the way that *readers connect objects through reading's work to create a "thread of meaning" from the various postings available for inspection*. Proximity may be more relevant to the sense making required in chat systems than contiguity. Chat systems are about posting objects for visual inspection that allow readers to make connections between these posted objects based on their availability for inspection and the features they display rather than on a strict notion of their position in a sequence. This means that sequentiality is not something that has to be built based on a notion of the contiguity of actions as in talk-in-interaction. Rather, *reading's work in chat is precisely the process by which actors constitute a sequence of actions as interaction from the production and inspection of available visual artifacts*.

The specific procedures by which readers and authors constitute interaction from the production and inspection of visual artifacts in chat have been described above. In chat, participants rely on the proximity rather than the contiguity of text posting and graphical objects as a way of achieving a sense of progression in their interaction. Specific lexical, grammatical and, in the case of graphical artifacts, graphical resources are used to link postings of various sorts, to demonstrate that postings are to be seen as linked and to display what that link consists of. In addition to using reference tools in the production of chat text, when available, to regulate one's own actions and the actions of others, actors indicate with the use of ellipses and other continuation markers (short and grammatically incomplete postings, etc.) that they are producing a series of postings that are to be read as a sequence, even though the postings may not be contiguous. When producing graphical objects in the whiteboard, actors use proximity and its achievement by moving objects within the whiteboard space to indicate they are producing the composite features of what is being produced as a single object. The temporal sequence of the production of whiteboard objects is not necessarily treated as a relevant consideration in the construction of whiteboard objects, whereas the locational proximity of these objects with respect to each other may be treated as relevant.

In chat environments, social interaction is the local achievement of reading's work, understood to be both the production and receipt of visual artifacts (both textual and graphical) that are designed to provide through their proper inspection adequate resources by which actors constitute:

- The presence of actors in the system,
- The co-presence of actors who are mutually orienting to each other and the actions they perform,
- The indexical ground of conditionally relevant objects and texts, and
- Indexical symmetry among participants with respect to these visual artifacts.

Online interaction using text chat is not an impoverished ("narrow bandwidth") version of talking, but a form of interaction with its own appropriate system of interactional practices. CSCL researchers wishing to analyze chats or to design environments to support chat should take into account the characteristics of chat interaction presented here.

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Tatiana: an environment to support the CSCL analysis process

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Abstract. The analysis of multimodal computer-mediated human interaction data is difficult: the diverse nature of this data and its sheer quantity is challenging enough, but a further obstacle is introduced by the complex nature of these interactions. In this paper, we describe the kinds of activities performed by researchers wishing to analyze this data. We present a model for analysis based on these activities. We then introduce Tatiana (Trace Analysis Tool for Interaction Analysts) as an environment based on this model and designed to assist researchers in managing, synchronizing, visualizing and analyzing their data by iteratively creating artifacts which further their understanding or exhibit their current understanding of their data. We show how Tatiana can be used to perform analyses and its potential for sharing corpora and analyses within the research community.

Introduction

The socio-cognitive study of human computer-mediated interactions can be performed through recordings of these interactive activities, particularly if they are not limited to interaction log files but also include audio and video recordings (Avouris, Fiotakis, Kahrimanis, Margaritis, & Komis 2007). Cox (2007) encourages researchers to use computers and the various techniques they offer (visualization, data mining etc.) to perform their analyses of interactions in what he calls “process data”. However, corpora of human interaction, particularly when these interactions are both face-to-face and mediated by computers are difficult to manage from a technological standpoint and complicated to understand and analyze due to the multiplicity and variation of source data. Indeed, it is not enough to look at individual data streams; different media streams must be combined to achieve a global understanding of the interactions that occurred (Goodman, Drury, Gaimari, Kurland, & Zarrella, 2006). Furthermore, it is often necessary to perform analysis as a team, be it in order to validate the analysis method through inter-coder reliability (De Wever, Schellens, Valcke, & Van Keer, 2006), to extend applicability of an analytical method to a new domain of application (Lund, Prudhomme, & Cassier, 2007), to spread the workload (Goodman, Drury, Gaimari, Kurnland, & Zarella, 2006), or to combine the insights of several analysts (Prudhomme, Pourroy, & Lund, 2007).

The difficulties described above suggest the necessity of tools which provide not only the means to manage this variety and quantity of data, but also to allow visualization and analysis within a common framework and in a way that can be shared with other researchers (cf. Reffay, Chanier, Noras, & Betbeder, 2008 for work on structuring learning corpora for sharing purposes).

In this paper, we will give an overview of a selection of the actions that are performed by researchers when analyzing human interaction data, particularly in the case where it is computer mediated. We will then present a simple model to describe this analysis activity and show how the analysis tool Tatiana (Trace Analysis Tool for interaction analysis) is designed to support this model, which we see as generalizable. More specifically, we will demonstrate how Tatiana can assist analysts in performing the actions we have presented. Finally, we will conclude by exploring how Tatiana is intended to assist new kinds of analysis and foster sharing and collaboration in CSCL research.

How do we analyze?

A typical CSCL corpus might assemble video and audio recordings, computer interaction log files, pre- and post- tests, interviews, field notes and experiment descriptions (design, context, etc.). In designing a tool to support the analysis of such a corpus, the question we have attempted to answer is "what do researchers do with this data?"

While we could approach this question from a methodological standpoint, achieving a reasonable coverage of existing practices in the CSCL and other closely related communities would require performing a meta-analysis of a very large body of research and to do so in a satisfactory way is beyond the scope of this article. In addition, if we did carry out such an analysis, it would show us what researchers are doing but it would not necessarily show how they are doing it, as that information is rarely reported. As designers of tools to support this process, this information has been difficult to come by on a larger scale. In this section, we will present our understanding of analysis activity by exploring a subset of analysis themes and the artifacts that a select number of researchers create in relation to these themes. To support our claims we will draw variously on case studies, papers describing methodological issues or experiments and tools that exist to support analysis. Finally we will present the model of analysis on which we have based the design of Tatiana.

Case Studies

In the context of the Lead(1) project (Lead, 2006), we have had the opportunity to follow the activities of four research teams with respect to the design and analysis of experiments related to the project. All these experiments focus on the use of computer-mediated communication in face-to-face situations (communication can be verbal or computer mediated). Analysis in these cases presents particular problems (Dyke, Girardot, Lund, & Corbel, 2007) one of which being the necessity of synchronized replay of data provided by computer log files and data provided by audio and video recordings in order to fully understand the situation. We were able to work in continued collaboration with one of the teams and had the opportunity for on-site visits with two other teams where we recorded and discussed their analysis activities. In presenting these case studies we cannot go into great detail as to the hypotheses and theoretical assumptions because they relate to as yet unpublished studies. We will however give an overview of the procedure that each team followed for some portion of their analysis (the part that is relevant to support our claims regarding how analyses are performed). The parallel development of Tatiana means that at least some of their analysis was performed with Tatiana, but particularly during on-site visits, we discovered requirements that we could not meet at the time. In this section we will be interested in the actual analysis steps that each team wanted to undertake rather than in the usage (or not) of Tatiana.

Lyon case study

We were our own main users of Tatiana during the initial development phase (variously wearing our tool development, usability tester and CSCL researcher caps). We observed nine dyads over the course of three to five meetings with their teacher for an introductory-level computer-programming project. These meetings took place face-to-face with the assistance of a chat and a real-time shared text editor (both of which the two students and the teacher had access to, on their laptops). The students were encouraged to take notes in the shared text editor.

In one analysis, we were interested in the provenance of these notes. Very often they are reformulations of utterances. We wanted to gain a deeper understanding of this reformulation from a linguistic viewpoint and explore possible pedagogical consequences. In order to do this, we first transcribed the dialogues. We transformed the interaction log data from the shared text editor into something we could understand. The nature of the shared text editor (Corbel, Girardot, & Jaillon, 2002; Corbel et al., 2003) means that the log data it produces consists of events which are recorded each second (provided changes have been made) and contain the full text, the name of the author who did the changes and the position of their cursor at the time of the change. We desired a much higher level of analysis, consisting of some kind of semantic unit. These events were therefore grouped together manually into writing units. We then annotated the reformulation links between the transcription and the writing units. Finally this was transformed into visualizations (cf. Figure 1) which allowed us to see certain interesting phenomena and to gain intuitive insight into the reformulation process.

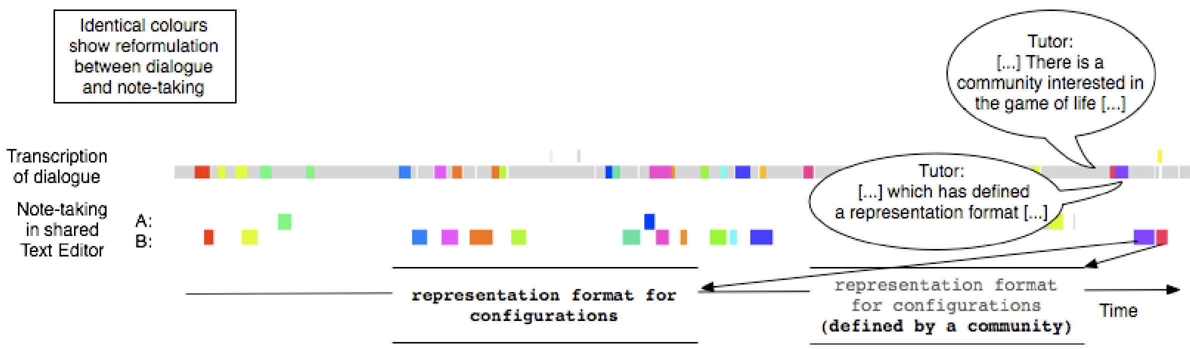

Figure 1. An example of a visualization of reformulation. The order of the utterances spoken by the teacher (top) is inverted in the students notes (bottom); however, the ordering is alluded to by the presence of brackets.

Paris case study

In this second case, we were on site for two days, discussing our colleagues current analysis practices and examining how Tatiana could usefully augment these practices. This resulted in audio and video recordings of our discussions along with usability testing of Tatiana which we will not report here. One of their analyses involved the long-term study of classroom adoption of the CoFFEE software (De Chiara, Di Matteo, Manno, & Scarano, 2007), developed during the LEAD project. They followed pairs of dyads who worked together in a shared workspace. Each dyad worked behind one computer and each pair of dyads (sitting at adjacent computers) worked in a common workspace. In this analysis they were specifically interested in the kinds of interactions (Bernard, 2008) that happened within a dyad (tool-focused vs. subject-matter focused, verbal vs. computer mediated, etc.) hoping to observe the link between the kinds of interactions and the dyad-dyad collaboration.

In order to do this, they wished to replay the video synchronously with the interaction log data, marking blocks as different types of interaction took place in each dyad. These interactions would then be categorized according to a coding scheme describing the different kinds of interactions thus enabling the side-by-side comparison of the interactions of each pair of dyads in relation to the computer-mediated interaction.

Utrecht case study

In this third case, we were again on site for two days, discussing current analytical practices, and examining whether Tatiana was adapted to them. This also resulted in audio and video recordings of our discussions. Their work focuses mainly on the production of argumentation diagrams (e.g., Overdijk & van Diggelen, 2008). One of their analyses methods consists in isolating from the log files only the events where boxes are created and then re-ordering these events to show the threading in the diagram, rather than the order of production (rather like threading occurs in threaded forums). From this point they are able to apply discourse or content analysis methods to the data.

Another analysis process they apply is the creation of visualizations that show how students' involvement across the various threads happens over time. These combined views (time-based, thread-based and student-based) enable a fuller grasp and better understanding of the situation (Lund et al., 2008).

Nottingham case study

In the fourth case we have not had an opportunity for on site visits but have (as with the other partners) had discussions during meetings and via email. One practice of interest to us is their use of statistical methods such as those available in SPSS and Excel. In one study, a follow-up on Gelmini Hornsby, Ainsworth, Buda, Crook, & O'Malley (2008), they were interested in how various conditions influenced change of opinion in a vote module in CoFFEE. The global pattern was first vote, discussion and second vote. Before each vote was closed, students could change their opinion any number of times and this was reflected in the log files. In this case, the researchers had to manually find the last opinion in each vote for each student, in order to observe whether an opinion changed between the first and second vote.

They also expressed interest in automated calculation of general kinds of statistical indicators in the discussion such as words per turn, words per turn per student, turns per student per topic etc. The rationale behind this being that any kinds of abnormal phenomena (e.g. unusually high or low participation) might be a starting point for further exploration. Finally, they confirmed the necessity of any new tool to be able to integrate with their current practices (e.g. Excel and SPSS, but also other analysis tools and transcription tools).

Some analysis themes

As we have previously stated, our aim is not to cover all (or even the majority) of analysis methodologies, their theoretical assumptions and the intricacies of their conditions of application. Rather, we use these analysis approaches to evidence a selection of the kinds of actions that analysts are led to perform.

Coding and counting

Several kinds of analysis make use of coding and counting, most notably content analysis (Strijbos, Martens, Prins, & Jochems, 2006). This is such a common practice that there is an increasing body of literature on various artificial intelligence techniques to help automate the task of coding (Rosé et al., 2008; Erkens, & Janssen, 2008). In the application of this kind of method, an important question is that of *unit of analysis* (De Wever et al., 2006); what is the pertinent granularity: e.g. a dialogue turn, propositional content within a dialogue turn, a succession of dialogues turns? Another question is that of the coding scheme to be applied, which can be drawn from the literature (e.g. Baker, Andriessen, Lund, van Amelsvoort, & Quignard, 2007) or created for the purpose of a specific analysis. Once this scheme is applied the question of *validation* of the coding (De Wever et al., 2006) must be raised. Finally some statistical tests must be applied.

Regardless of the choice of analysis unit, the corpus must be broken up into such units. This segmentation is performed differently, depending on the type of media. Dialogue and human gestures from audio and video is typically transcribed using tools such as Elan (http://www.lat-mpi.eu/tools/elan/). Computer based interaction log data is transformed into a series of actions which are then regrouped or re-segmented. In both cases, the resulting data is in the abstract form of events (or actions) with a series of properties such as time, user/speaker, content, tool, etc. More concretely, such data can typically be found in an Excel™ spreadsheet with one row per event and one column for each property. In the case of existing software support, tools such as Elan, Videograph® (http://www.ipn.uni-kiel.de/aktuell/videograph/enhtmStart.htm) and DRS

(Digital Replay System, Greenhalgh, French, Humble, & Tennent, 2007) enable the direct annotation and coding of video in the way suggested by the desired practice of the Paris case study.

Coding or rating schemes are diverse in nature. They are often created through an iterative process involving partial coding of a corpus and subsequent redefining of the scheme, or even through collaborative coding (De Vries, Lund, & Baker, 2002). It is rarely the case that a coding scheme is directly applied without further modification. This point is important for software design as it means that evolving categorization schemes must be taken into account.

Coding can then be seen as adding one or more properties to each event by a coder. The subjective nature of this activity combined with the desirability of subsequently applying statistical methods to coded data necessitates the validation of the coding. It is common for intercoder reliability to be applied (De Wever et al., 2006), which, regardless of the metric used (Cohen's kappa, Krippendorf's alpha, etc.) usually involves comparing two or more codings (complete or partial) side by side.

Data is then collated by counting various codes according to other characteristics (e.g. user, group, tool). By observing the distribution these codes and through the application of statistics certain kinds of hypotheses can be confirmed or infirmed.

Bookmarks, collections and annotations

Other kinds of analysis, most notably through case studies (e.g. Rummel, & Hmelo-Silver, 2008), in the field of conversational analyses (Sacks, Schegloff, & Jefferson, 1974) and analyses based on activity theory (e.g. Avouris et al., 2007), consist of describing corpora by adding annotations, creating collections or groups of events. This can be done manually (in a text file or spreadsheet) or through the direct support of tools such as ActivityLens (Fiotakis, Fidas, & Avouris, 2007), Videograph or Transana (http://www.transana.org/).

Synchronization in time

The analytical necessity of synchronization of different data sources and analysis artifacts is plain: the observed events — at the time of observation — were temporally situated and must be replaced in this context to be understood. Furthermore, different views on the same data (e.g. video and transcription) complement each other well when they are synchronized. In fact, it is a scientific necessity to have this synchronization (or some other means of returning to the primary data); when making a claim the question that is always asked is: "is there evidence in the data to back up this claim?" Analysts frequently make use of artifacts that present the corpus in a way that is more readily understandable, browsable or analyzable (compare transcriptions and the video/audio they transcribe). However, when a claim is postulated based on information found in one of these "secondary" artifacts, it is necessary to verify that the original data also evidences the claim that is being made. Synchronization presents a way to easily refer back to the primary data at any point where confirmation of a claim is needed.

Synchronization of different media sources is further justified by the number of tools that enable it to a greater or lesser degree: Elan, ActivityLens, DRS, Replayer (Morrison, Tennent, & Chalmers, 2006) and ABSTRACT (Analysis of Behaviour and Situation for menTal Representation Assessment and Cognitive acTivity modeling; Georgeon et al., 2007; Georgeon, Mille, & Bellet, 2006) all enable synchronized replay (c.f. Figure 2) of the analysis artifacts which they are designed to create and handle.

Figure 2. In this example from Replayer, the events selected in the left hand view are also highlighted on the map and in the video timeline on the right (http://www.dcs.gla.ac.uk/%7Emorrisaj/Replayer.html).

Graphical Visualizations

As our examples in the Lyon and Utrecht case studies show, graphical visualizations allow researchers to look at data through a different lens and often help in isolating interesting phenomena or give an intuitive insight into what happened. A typical form of graphical visualization is a symbolic representation of events on a horizontal timeline. This feature is pervasive, being present in SAW (Synchronized Analysis Workspace, Goodman et al., 2006), ABSTRACT (cf. Figure 3), Replayer, DRS and others. In this case, visualizations can be used to explore the temporal dimension of the data. Suthers & Medina (2008) augment these visualizations with complex annotations, allowing the visualization to become a means of recording knowledge gained from analysis and for communicating this knowledge to a wider audience. Teplovs & Scardamalia (2007) use the information found in log files of a threaded forum to generate interactive visualizations which group similar posts on criteria such as common author, common threading and semantic proximity. There are many other kinds of visualizations which aim to convey some kind of analytical knowledge about data such as the generic argumentation diagrams describing design produced by Prudhomme, Pourroy & Lund (2007) or those which are related to awareness tools such as those presented by van Diggelen, Jansen, & Overdijk (2008).

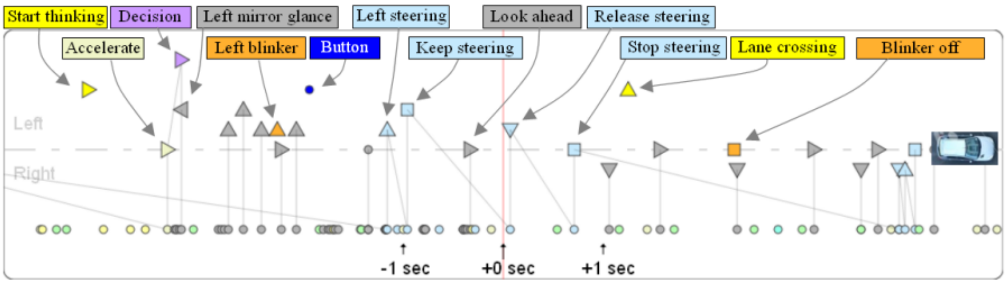

Figure 3. Symbolic graphical representation of events recorded during a lane change on a motorway, viewed in ABSTRACT (http://liris.cnrs.fr/abstract/).

Interoperability and sharing

Reffay et al. (2008) note the importance of being able to share CSCL corpora. Kahrimanis, Papasalouros, Avouris, & Retalis (2006) examine how greater interoperability between CSCL log data and analysis tools can be achieved. Our case studies tell us that researchers have existing practices which are tried and trusted, and that they do not feel safe putting all their eggs into the basket of one tool. We are ourselves interested in the possibilities generated through the sharing of analyses as a means of validation (such as the kind provided by inter-coder reliability) or as a means to gain a holistic understanding through the combination of analyses from experts in different domains (e.g. Prudhomme et al., 2007).

A simple model of analysis

Harrer et al. (2007) have modeled the analysis process with a view of basing the design of analysis tools and interoperable formats on this model. They propose that analysis can be seen as a sequential process going through phases of capture, segmentation, annotation, analysis, visualization and interpretation.

Our current understanding of analysis, based on our case studies and our past experience (Lund, Rossetti & Metz, 2007; de Vries et al., 2002; Prudhomme et al. 2007; Baker, et al. 2007), is that the most important part in this model is the iterative loop: researchers who arrive at the interpretation phase and are not satisfied with their results incrementally improve the analysis of their data until they arrive at a satisfactory result which can be reported to the scientific community. Contrary to what can be seen in Figure 4, we do not believe it is necessary to go through all the phases in a particular order or to wait until the interpretation phase to iterate. For example, segmentation of data into units of analysis has often been seen in our case studies as being unavoidably entangled with the kind of coding that will later be applied; an inability to apply a coding to a certain unit can lead to a slight change to the segmentation.

We have based our design of Tatiana on a similar (but less detailed) model that puts more focus on the iterative nature of analysis (cf. 4). Analysts constantly evaluate whether their current collection of primary data and secondary artifacts is sufficient. If it is not, they create a new artifact that is intended either to further their understanding of the data or to reify their current understanding of the data.

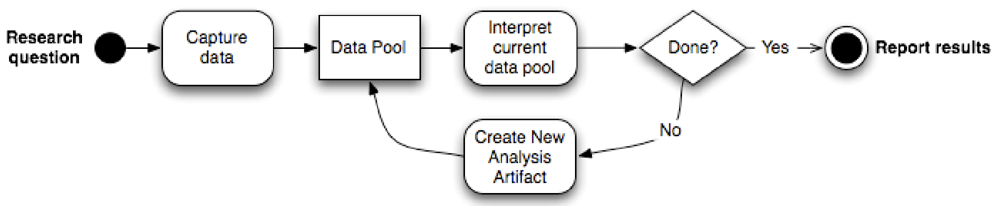

Figure 4. Graphical representation of the analysis model which Tatiana is designed to support

In the analysis themes presented above, we have seen the variety of artifacts that researchers create. Sometimes the creation of these artifacts can be automated (e.g. transforming data into a new representation or performing statistical analysis). Sometimes it is manual (e.g. creating certain kinds of visualizations) and sometimes it is tool-assisted (e.g. transcription, annotation and coding). These artifacts are frequently ways of representing data with some kind of temporal dimension through different lenses: the sequence of events recorded in the observation is made available to the researcher, either by presenting it in a media player (the researcher uses a remote control to navigate the data) or in some kind of graphical or tabular representation (where time is plotted along a vertical or horizontal axis).

These artifacts can be classified into three kinds. *Collations* aggregate data over a time period producing data such as indicators and statistics. *Analyses* are artifacts which add researcher created analytical knowledge (such as codings, annotations and relationships). Finally, we propose that the kinds of artifacts which retain some notion of ordering of events and interactions in time be termed *replayables*. These are objects that can be replayed, synchronized and analyzed. We further propose that the analysis process consists of the iterative creation of new artifacts (such as replayables and analyses) that exhibit researchers' understanding of their data or that allow them to further this understanding. We are particularly interested in replayables as they are the most frequent source for creating new artifacts, other replayables in particular. The transformations from replayables into other artifacts include transcription, annotation, coding, visualization, filtering, synchronization, merging and collation. It should be noted that the creation of analyses might be assimilated to creating a new replayable where each event has a new set of properties. However, by considering analyses as separate entities, they become reifiable objects which can be shared with other researchers who are already in possession of the same corpus and can be overlaid on top of other replayables representing the same data.

Tatiana: a generic analysis environment

In the previous section, we describe how researchers perform their analyses. While many tools currently exist to assist some of these tasks, even the most generic of them such as ActivityLens and Digital Replay System lack several features such as automated transformations, the ability to include new kinds of data and the extensibility to adapt to new kinds of analyses. Tatiana (Trace Analysis Tool for Interaction ANAlysts) is an environment designed for manipulating the kinds of artifacts described above, replayables in particular. In this section we briefly present the features of Tatiana which make this possible.

Tatiana overview

Tatiana is built on a number of core concepts and components (cf. Figure 5). Tatiana replayables can be created either automatically (through import) or by hand. Once created, all replayables in Tatiana benefit from Tatiana's four core functionalities: transformation, analysis, visualization and synchronization.

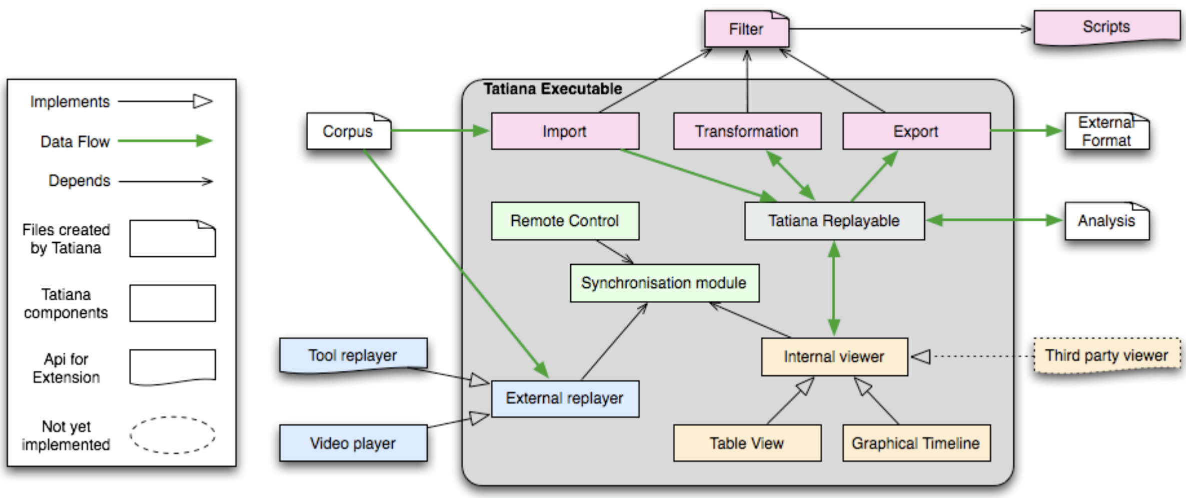

Figure 5. Tatiana architecture showing 1) dependencies between components, 2) components designed with extensibility in mind and 3) future developments.

Transformations

Replayables can be transformed (again, automatically or manually) and exported. Automated import, transformation and export works through the application of what we call *filters*. These are objects which combine *scripts* into a workflow. Scripts are small programs written to perform a specific operation, such as transform a file in the corpus into data Tatiana can understand, exclude certain kinds of events from a replayable, find certain kinds of events in a replayable, combine multiple replayables, etc. As we do not expect researchers with no programming knowledge to write these scripts, we are currently developing a graphical editor for filters which will allow researchers to customize the execution of these scripts. Such a filter might combine a new script for data import from the interaction log data produced by a new kind of tool with an existing script which only shows the actions of a particular subset of students. Manual transformations include the ability to delete, reorder, re-group and split events.

Analysis

All replayables within Tatiana can be augmented by analysis data generated by the researcher. There are currently two kinds of analyses supported by Tatiana: annotations (for free-form annotation) and categorizations. Categorization is simply a way of adding annotations from a restricted list of words and can be used for coding, labeling and adding keywords. The list of categories available can be edited at any time thus allowing for an evolving analysis scheme.

Visualization

All replayables within Tatiana can be visualized in different viewers. There currently exist two kinds of viewers: a table view in which data is presented as it might be presented in Excel, with one row per event and columns for each of the event's properties and a graphical timeline. The graphical timeline is a first attempt at assisting the automated creation of visualizations. It presents each event as a graphical object whose graphical properties (color, shape, size, position, etc.) can be set according to the properties of the event (user, tool, timestamp, analysis category, etc.). We plan on making Tatiana extensible so that new kinds of visualizations of replayables can be created while benefiting from Tatiana's other core functionalities.

Synchronization

Finally, all replayables in Tatiana can be synchronized with each other and also with data viewed in external replayers such as media players and tool replayers (a special mode of certain CSCL tools which are capable of reading the interaction log data they generated and reproducing on screen what the user saw). Tatiana provides a mechanism to pilot external tool replayers. Synchronized replay means that when a timestamp is selected in the "remote control", the video player (and other external replayers) are instantly navigated to that timestamp, and the events matching that timestamp in the currently visualized replayables are highlighted. Furthermore, selecting an event in a visualized replayable will again navigate all the other views to that moment in time. For example, during analysis of a discussion of genetically modified organisms using Tatiana, if a researcher clicks on the timestamped event in the table view "argument by Alice: they go against ethics" this action causes the replayer to show the state of the diagram immediately after that argument was constructed. Information on the dynamics of the interaction in thus provided, which is oftentimes difficult to discern in static log traces. Zooming in on particular episodes becomes possible. In general, such linking between replayables is very useful for limiting the amount of information displayed in a single visualization, with the knowledge that further information is available in other visualizations on demand.

Sample use of Tatiana

Typical usage of Tatiana consists of iteratively creating replayables and analyses, gradually increasing and exhibiting the researcher's understanding of his or her corpus. To illustrate, we show how we used Tatiana in the Lyon case study to analyze reformulation of dialogue into notes in a shared text editor (cf. Figure 6).

The artifacts created can all be seen under Tatiana synchronization. Transcription was performed outside of Tatiana and then imported as a replayable representing transcription. The interaction log data at low granularity was grouped together into a replayable representing writing units. The writing units and transcription were analyzed, giving identical labels and colors where reformulation occurs. The writing unit and transcription replayables were merged, and visualized as a graphical timeline with transcription on the top row and writing units on the bottom row. Identical colors show which utterances in the transcription have reformulations in the shared text editor. Transcription, grouping and analysis was performed by hand (with tool assistance), but all the other transformations were automated.

In order to give meaning and context to the data produced in the shared text editor, we can observe in the replayer (here DREW is used: Corbel, Girardot & Jaillon, 2002; Corbel et al. 2003) and in the video exactly what happened at a given time.

Tatiana usage and limitations

Tatiana was developed in parallel to the analyses carried out in our case studies. Its features enabled us to carry out our work in the Lyon case study and are now adequate to assist in performing the analyses in the other cases. Further analyses are expected to be carried out with the assistance of Tatiana in coordination with other tools (such as Excel and SPSS for statistical analysis and Elan for transcription).

There is currently limited support for collations in Tatiana. Such data is difficult to synchronize, analyze and visualize in the same way as for replayables. However, transformations do exist to produce limited statistics such as contingency tables which can then be exported to other formats such as Excel. Once generated, replayables and analyses can be saved and shared with other researchers.

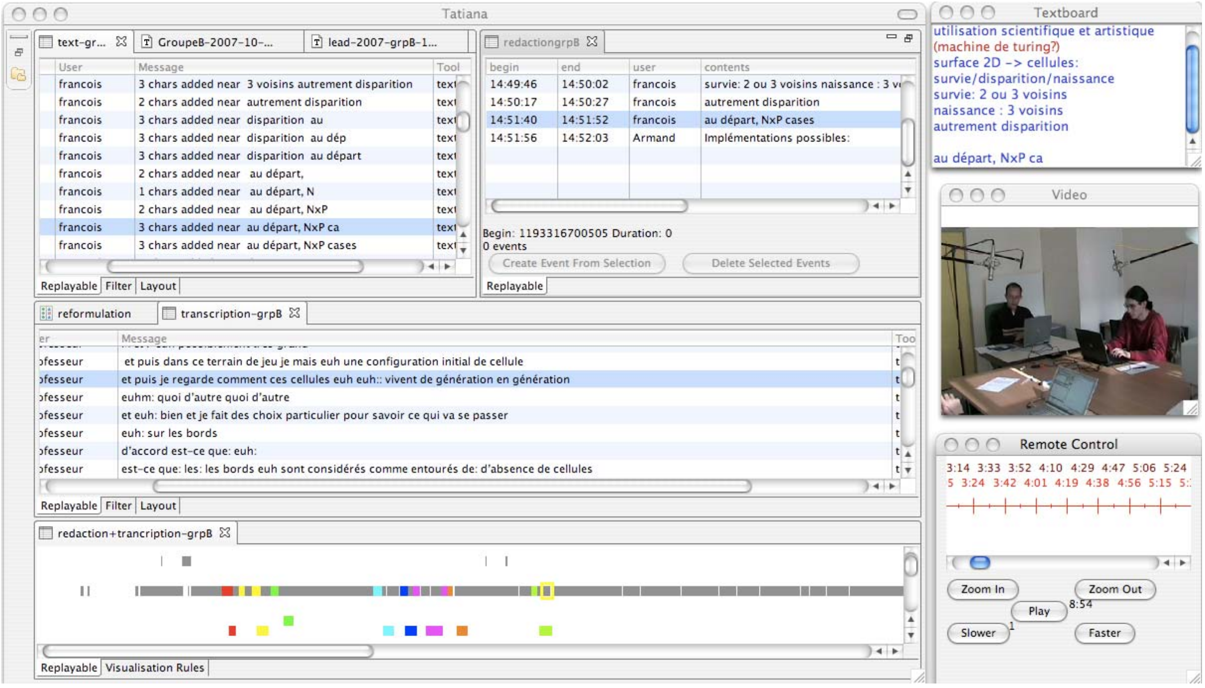

Figure 6. Various replayables in Tatiana: traces of a shared text editor (top left), transcription (middle left), writing units (top center), visualization of reformulation (bottom left), synchronized with external tools, DREW replayer (top right), video player (middle right), remote control (bottom right).

Conclusions and Future work

In this paper, we described many of the activities performed by analysts when analyzing CSCL and related corpora. Based on these activities, we presented a model describing the analysis process. In this model, researchers iteratively create new artifacts which afford them new understanding or exhibit their current understanding of their corpus. We identified a particular time based artifact which we call a replayable. We then presented Tatiana, a tool whose design supports the iterative creation of replayables. We described the main features of Tatiana with regard to creation, transformation, export, analysis, visualization and synchronization of these replayables.

Tatiana responds to the inherently iterative and diverse nature of socio-cognitive interaction analysis by providing flexible data transformations and visualizations and by providing several extension points in order to meet new needs such as creating new transformation filters and providing additional views for the creation and iterative improvement of replayables. Such new views could be similar to the visualizations suggested by Suthers & Medina (2008), or Teplovs & Scardamalia (2007). The difficulty in recreating what participants experienced during corpus collection on the basis of the recorded data is answered through multiple synchronized visualizations of the data, and through the integrated use of external tool replayers. Finally, through the ability to save and share analyses, Tatiana enables researchers in the human and social sciences to work as a team and to integrate and compare their analyses.

Our future work will involve simultaneously bettering our understanding of CSCL and CSCW researcher's analysis methodologies and further developing Tatiana as an environment for managing replayables (and other analysis artifacts). We will strive to make this framework more coherent, and to assess the extent to which researchers with no programming experience can fully use the power provided by Tatiana.

We hope that in making Tatiana and similar tools more widespread, we will enable researchers to make better sense of their corpora and to share the knowledge they have created with other researchers. We also hope that this will enable us to gain more insight into the process of socio-cognitive interaction analysis, making it easier to evaluate and share methodologies, corpora and analyses throughout the CSCL community.

Endnotes

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The Needlework in evaluating a CSCL system: The Evaluand oriented Responsive Evaluation Model

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Abstract: This article presents the Evaluand-oriented Responsive Evaluation Model (EREM), a comprehensive evaluation model to be used in the evaluation of a CSCL system. The model relies on a responsive evaluation approach to provide potential evaluators with a practical tool to evaluate multiple criteria and episodes.

Introduction: Initial Stitches

In 1927 theoretical physicist Werner Heisenberg articulated his uncertainty principle. Roughly speaking, it states that the position and velocity of an object cannot both be measured exactly at the same time, and that the concepts of exact position and exact velocity together have no meaning in the small scales of atoms and subatomic particles. We find the principle useful to illustrate the uncertainty involved in the evaluation of CSCL programs, courses, learning strategies, projects, and technological tools.

Evaluation is intrinsic to human life, hence complex and intricate. We are always balancing things, decisions, opinions as to whether or not ask something, do something, etc. Stufflebeam (1971) and Cronbach (1980) defined the main goal of formal evaluation as improvement in decision-making. But there are many purposes even for a single evaluation study (Stake, 2003).

CSCL is an interdisciplinary field different from other applications of ICT to learning and/or collaboration. This difference is its emphasis on group learning. Its theoretical foundations consider knowledge as a learner construction promoted by the interaction of learners with their social and physical environment. For Koschmann (2002) CSCL is "a field of study centrally concerned with meaning and the practices of meaning-making in the context of joint activity and the ways in which these practices are mediated through designed artifacts." The design and enactment of CSCL systems and scenarios is inherently complex, with a wide mix of disciplinary perspectives. Teachers, curriculum designers, evaluators, students, and technology developers work together. Comprehensive evaluation of these systems is challenging. Treleaven (2003) argues that "evaluation in these contexts challenges traditional approaches to evaluation and requires new theoretical frameworks to guide analysis and interpretation."

The different conceptions of the CSCL field, the strong social component that defines it, and the multitude of value questions surround the evaluator in uncertainty. Many criteria standards issues and interpretations of a complex system remain open even at the end of the study.

In this paper we present an evaluation model to be used by CSCL practitioners and evaluation specialists called Evaluand-oriented Responsive Evaluation Model (CSCL-EREM). The model is framed within what Lincoln and Guba (1989) have called the "Fourth generation of evaluation". Evaluators respond to participants´activity more than measuring them. The model orients the evaluator to the systemic activity, noting the uniqueness and the commonality of the evaluand to be evaluated. The evaluator is responsive to key issues and problems recognized by participants at the site (Stake, 2003).

Looking for the right Needle: Need for a comprehensive evaluation framework in the CSCL field

Often it is difficult to find a common conceptualization of CSCL among educators, evaluators, computer scientists, psychologists, and engineers, partly because their experiences differ so much. A comprehensive evaluation framework should help identify the diversity of their concerns, promoting a realization that evaluation studies answer some questions, mention others, and necessarily ignore most of them.

Many people see the CSCL field as more socially ambitious than other areas of ICT (Stahl et al, 2006). This fact constitutes a challenge to program evaluation (Treleaven, 2003) for developers, instructional designers and evaluators. An evaluand-centered evaluation framework (as opposed to technology-centered, personnel-centered, and policy-centered evaluation) should help guide evaluation toward holistic viewing. Some features of CSCL can be assessed along a single variable, but a comprehensive evaluation requires the broad study of functions, sequences, relationships and settings. Each event gives meaning to the next, each shortfall to the vigor of its neighbor.

The continuous development of new platforms and tools for collaboration and computer-mediated learning calls for far-reaching evaluation of the systems. At times, the learning environment should reign over the technical artefacts. Determining if meaningful educational practices are taking place requires the identification of criteria and critical events that determine the educational quality of a CSCL system (Crawley, 1999). Other evidence of the need for a comprehensive evaluation framework can be found throughout the literature.

Some proposed frameworks are good for particular questions, such as the *Object Oriented Collaboration Analysis Framework* (OCAF) (Avouris et al, 2003), a framework for the analysis of interaction processes. Other frameworks such as the *Groupware Framework* (Gutwin & Greenberg, 2000) focus on specifics like groupware usability. Some frameworks, such as the *Communicating Model of Collaborative learning (CMCL)* (Cezec-Kermanovic & Webb, 2000) are found hard to make practical. Some evaluation frameworks draw data only from stakeholders; others, such as Pinelle & Gutwin's *Framework* (2000) and the *CMCL framework,* were designed to be used formatively by developers. Such frameworks can be valuable, but for systemic understanding, the entire evaluand needs to be studied.

Our twelve-year experience with the evaluation of CSCL systems has helped us identify requirements (Table 1) for a model that is comprehensive yet adaptable to settings and conditions. Our research team has evaluated a variety of undergraduate CSCL courses (Martínez-Monés et al, 2006; Jorrín-Abellán et al, 2006), teaching strategies (Martínez-Monés et al, 2006) and tools and technological systems (Hernández-Leo et al., 2006; Vega-Gorgojo et al., 2008). This fieldwork experience has turned us progressively toward qualitative/interpretative evaluation where the uniqueness and particularity of each system becomes the ground for evaluative interpretation. Many of our evaluation facets have been aimed to account for participant needs. And so, even for the evaluation of technological tools, EREM includes a range of data-gathering techniques to generate rich descriptions and to find the panoramic outcomes of the evaluand.

We built our EREM approach from Greene's multiple methods model (2001) and Stake's responsive evaluation (1973). We see our EREM framework as fitting Guba and Lincoln's (1989) fourth generation of evaluation, which named the four generations as: measurement, description, judgement and negotiation. When compared to other program evaluation approaches EREM is oriented more to the activity, the social context, and the uniqueness of the evaluand. Its design is organic, re-adaptating the evaluation goals and data-gathering. We have watched the growing interest in interpretative evaluation methods in the CSCL field, noting particularly the work of Suthers, 2006; Koschmann et al, 2005 and Ares, 2008. We know that on many occasions evaluators will need a more quantitative or narrower evaluation. We respond here to occasions calling for comprehensive evaluation review of a CSCL system.

This section has shown some of the needles for the embroidery of evaluation of CSCL systems. These needles suit the threads described earlier and constitute the mind-set for the comprehensive CSCL evaluation model we propose in the following paragraphs.

Table 1: Initial sketch of the characteristics that can be demanded to a CSCL evaluation framework

Characteristics that can be demanded to a CSCL evaluation framework
The traditions/perspectives involved in the field highlight the need for a flexible enough framework to give answer to the needs and goals of the many different stakeholders. At the same time it should be robust enough to provide a common evaluation model shared by the CSCL community
The importance of the social component of learning in the field recommends the definition of an evaluation framework oriented to the activity, the uniqueness and the plurality of the evaluand to be evaluated. It should also be sensitive to key issues or problems recognized by people at the site, giving voice to the participants.
The many possible evaluands that could be evaluated from diverse traditions reveals the need for a framework that should propose many different data gathering techniques.
The applicability of the framework as well as the consensus intended among CSCL practitioners highlight the need of an evaluand-oriented framework

The frame to Needlework: CSCL-Evaluand oriented Responsive Evaluation Model (CSCL-EREM)

Evaluation of CSCL systems can be seen as "embroidered patchwork", a form of needlework frequently done in the past by people around a frame. This metaphor describes the sort of evaluation model we propose in this paper. The EREM is to be a framework for helping in the evaluation of CSCL programs, innovations, learning and teaching resources, teaching strategies, tools, and CSCL institutional evaluations. The aim of the model is to provide clear, understandable and action-oriented guidance to CSCL practitioners involved in the evaluation of a CSCL system. It is deeply focused on the different evaluands that could be evaluated in these settings, and it is framed within the *Responsive Evaluation* approach. The model is intended to promote responsiveness to key issues and problems recognized by participants at the site. As can be seen in Figure 1, the model´s core parts are: Three *facets* (perspective, ground and method) that summarize some characteristics that could be taken into account while conducting an evaluation of a CSCL system; *four question-oriented practical courses* (pathways) according to the possible evaluands that can be evaluated; *a representation diagram* with the aim of helping evaluators in the planning stage of an evaluation; and finally *a set of recommendations to write the report of an evaluation*. Although we are proposing an ambitious model, it does not try to discover anything new in the CSCL field nor "to reinvent the wheel". The aim of this work is to provide clear and practical guidance to those CSCL practitioners that are novice in evaluation, by proposing a particular organization of the complexity of the field. Thus, the model can be interpreted as an effort to minimize the evaluation uncertainty discussed in the beginning of this article.

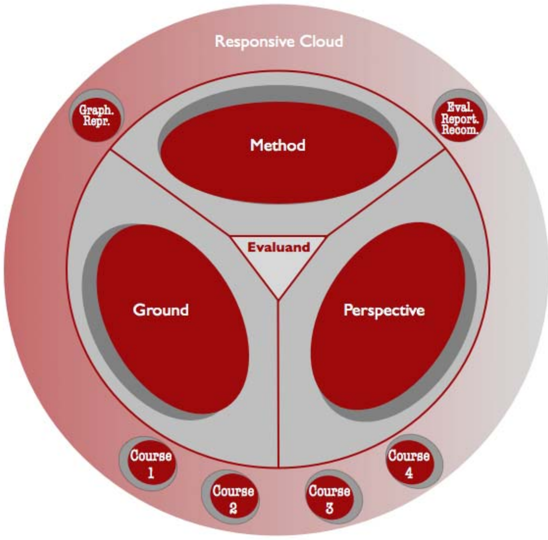

Figure 1. CSCL-EREM Components

Facets of the model

The first component of the model brings together some of the aspects that can be studied in the evaluation of a CSCL system. We have grouped them into three different facets. The first one is called Perspective and it can be understood as the point of view based on which an evaluation process can be both designed and carried out. Its emphasis relies on the main goal from which we are performing an evaluation. The main goals of a CSCL evaluation can be: To improve the educational practice; to improve the design of a tool; to monitor the progress of something within a CSCL system or; to support a research process. The second facet, called Ground, can be defined as the state of the environment in which a CSCL system exists. It can be considered as the context in which an evaluand takes place or is intended for, taking into account the characteristics of the evaluation we want to perform (extension, number of evaluators, experience in evaluation, etc), the main features of the participants (number, learning and teaching styles, previous knowledge, etc) and the features of the setting in which we are going to evaluate (climate, grade, extension, etc). The third facet, the Method, refers to the sequence of steps that lead the evaluation process, involving reasoning, observations, data collection, data processing, analysis and interpretation. The sort of evaluands that can be evaluated in these special scenarios differ so much; because of this, the model proposes many different data gathering techniques, with the aim of becoming an umbrella model where different traditions and ways of evaluation would coexist. The model encourages the use of mixed data gathering techniques as well as a variety of informants, in order to provide multiple perspectives to enrich the evaluation process. A profuse set of data gathering techniques like observations, interviews, expert reviews, costing techniques, heuristics, cognitive walkthroughs, social network analysis or feature inspections are proposed.

Courses

To bridge the gap between theory and practice, the model proposes four courses or pathways according to the different evaluands that could be evaluated in a CSCL system. Each one is formed by a set of questions that epitomize the aspects included in the described facets, helping evaluators to recognize some relevant issues that could affect their evaluand. The courses are: Evaluation of CSCL programs, innovations, courses; Evaluation of CSCL tools; Evaluation of teaching strategies/learning resources to promote collaboration; and Evaluation of CSCL projects. The model provides not only four different question-oriented paths but also real examples of evaluations performed by using them. Each course is expected to be used by different CSCL practitioners dependeding on their needs and interests.

Representation Diagram

Sometimes small management artefacts help to better planning an evaluation, thus contributing to improve its quality. The model proposes a representation diagram that supports evaluators to plan an evaluation in a practical and contextualized way. Figure 2 illustrates the evaluation planning of a blended undergraduate course on ICT to preservice social educators. More details on this evaluation can be found in Jorrín-Abellán & Stake (2009). The representation shows the aspects considered within the three facets of the model, as well as a brief schedule of the evaluation according to the data gathering techniques, the informants and the supportive technologies used. The lower right side of the circle shows the issues that guided the evaluation. These issues serve as conceptual organizers of the evaluation, helping evaluators to focus on the desired tensions of the evaluand.

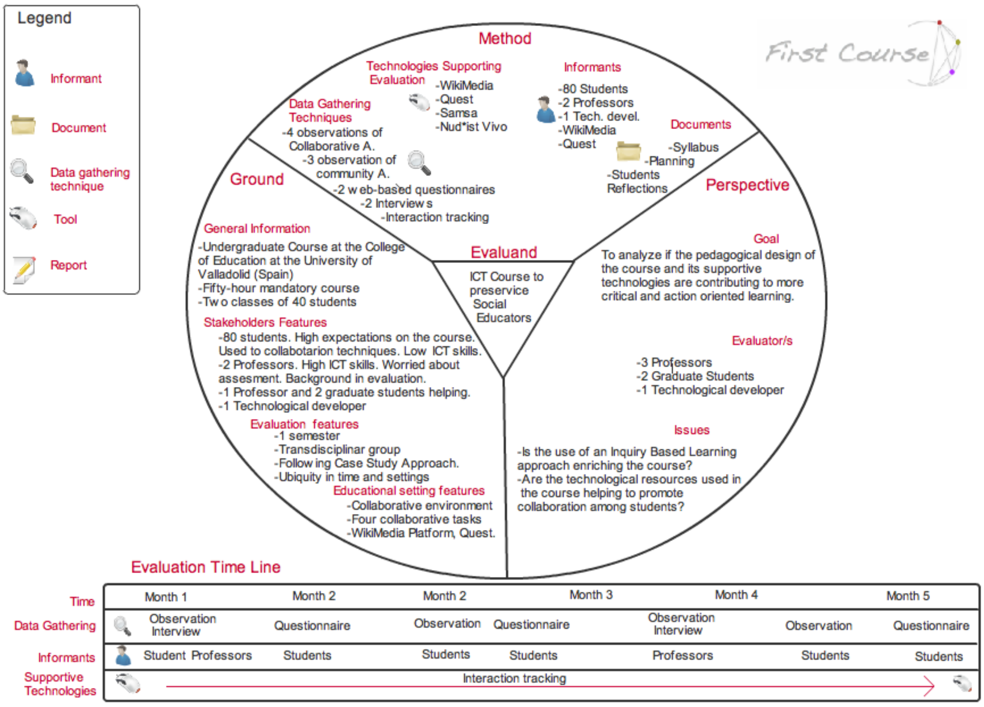

Figure 2. CSCL-EREM Practical examples

Recommendations to write the final report

The end product of an evaluation is expected to be a report. It constitutes the joint construction that emerges as the result of the evaluation; its synthesis. Many times the effort required to write it goes further than the quality of the evaluation conducted. As evaluators we are not only asked to provide results but to disseminate them in the best way. According to this, the model also includes a set of general recommendations, emerged from the practice, on how to manage the final report of the evaluation of a CSCL system. For instance, the feedback from responsive evaluation studies is expected to be in forms and language attractive and comprehensible to various audiences. Thus, it should be advisable to consider it in the early stages of the evaluation in order to decide the kind of reports to be made. Other critical aspects such as advocacy, credibility and triangulation are also taken into account in this final component of the model.

Conclusions and Future Work

In this article we have presented the Evaluand-oriented Responsive Evaluation Model. It is conceived as a comprehensive evaluation model that could be used to evaluate a wide range of CSCL systems. The model relies on a responsive evaluation approach providing potential evaluators with a practical tool to show evidence on how things work in a particular CSCL system. The model aims to promote mutual understanding among the different backgrounds and perspectives involved in the evaluation of CSCL systems by offering profuse evaluation criteria. Moreover, it has been developed with the aim of guiding the evaluation of a CSCL system as a wholistic and interconnected situation, showing that its effects can not be reassumed along a single variable. Likewise, it strengthens the necessity of conducting evaluand-oriented studies instead of encapsulating evaluations of the particular field of whomever is evaluating. The EREM model is a practical tool that provides four question-oriented evolving courses, a representation diagram, and real examples of yet conducted evaluations, suggesting the steps to be followed by evaluators conducting issue-driven evaluations. We are currently working to provide access to the model as a web-based tool. An evaluator would then select one of the aforementioned courses and the tool will guide her through the evaluation process proposed by the model. Users are also likely to benefit from expertise achieved by other evaluators sharing their evaluation designs. The web-based tool is accesible at http://titan.tel.uva.es/wikis/cscl-erem.

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A Model-Based Coding Scheme to Analyze Students' Organization

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Abstract: In this article we present how we use Bardram's model of collective work dynamics [1] to elaborate a conceptual tool for coding and analyzing the self-organization of students involved in a mediated (computer-based) pedagogic collective challenge.

Introduction

We define a pedagogic collective challenge as a CSCL learning situation where: (1) the problem set is designed to make learners practice target domain-related and/or meta-cognitive competencies; (2) a group of learners is involved, as a team, in the solving of the problem; (3) the solving requires the learners to join their forces; (4) the problem and the setting are designed to create a positive tension that motivates learners. Such challenges aim at enhancing learners' motivation in involving themselves in the collective solving and, within this process, in knowledge generative interactions such as conflict resolution, explanation or mutual regulation [2].

Challenges, as CSCL scripts, correspond to particular cases of collective work situation: learners are mutually dependent in their work [3]. This requires the overhead activity of articulating their respective activities [3, 4]. When learners only communicate via a computer-based system, taking these organizational dimensions into account is a core issue as they (1) impact the overall process and (2) conduct learners to be involved in knowledge-generative interactions. Our research aims at understanding these issues and how to help students in organizing themselves. For this purpose, we have engaged in the design of a computer-based system that (1) supports learners in organizing themselves and (2) supports human tutors in monitoring and supporting the learners' process. The design principles of our prototype [2] are inspired by Bardram's theoretical model of collective work dynamics [1]). In order to attempt understanding students' activity in its relation to this model, we have elaborated an analysis grid based on this model. The results presented in this article are (1) this analysis approach and (2) the lessons learned from an exploratory use of this analysis approach on two groups.

Bardram's model (cf. Fig. 1) focuses on collective work dynamics. It stresses the fact that perceiving breakdowns appearing during collaboration is an important dimension of the understanding of the collaboration dynamics, and the importance of supporting the dynamic transitions that may occur from one level to another during the activity (these levels corresponding to analytic distinctions: an activity takes place simultaneously at all levels.). At the co-ordination level, actors concentrate on the task they have been assigned to. Their work is related to a common goal, but their individual actions are only externally related to each other. They realize the global task from the point of view of their individual activity. Co-operation is an intermediate level where actors are active in considering the shared objective. This enables them to relate to each other, and make corrective adjustments to their own and others' actions according to the overall collective objective. Co-construction is the level where actors focus on re-conceptualizing their own organization and interaction in relation to their shared objects. Bottom-up transitions are related to an analysis of the object or the means of the work, which can occur in relation to a breakdown or an explicit shift of focus. Top-down transitions are related to the solving of problems and contradictions, and lead to a stabilization of the object and means of the work.

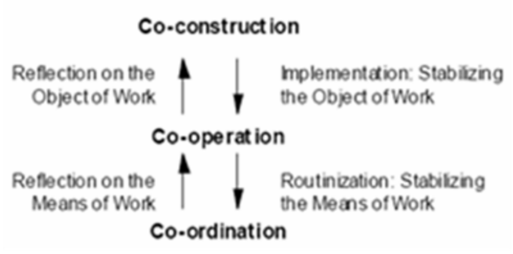


Figure 1. Bardram's model [1]

As a case study, we use a mathematical problem based on a car race simulation. The challenge (see [2] for details) has 3 phases: (1) preparing data (measuring data related to the cars' behavior such as speed or dynamics), (2) achieving different calculus in order to define a given set of values that will allow obtaining a target state and (3) launching the simulation to check the results. In order to succeed at phase 3, students must organize themselves, i.e., decide what to do, who will do it, and how. With respect to the co-construction level (cf. [2] for details), the prototype proposes a shared interface: the simulation, a collective "data description" editor, and communication tools (a chat and voting tools) to discuss, add or suppress a line in the data description table. The data description editor allows students (and suggests) collectively defining the data they will need to solve the problem: the level of priority of the actions to be processed (e.g., "high"); the involved notion (e.g., "cars that stop"), the name that is adopted by the group to denote the data (e.g., "duration of the stop"), a textual description of the data and the action to be realized in relation with this data (e.g., "measure"). The result (a list of lines) is a kind of general problem solving plan. With respect to the co-operation and co-ordination levels, students are then presented with a shared planning definition/execution editor. For every couple data/action (e.g., “all cars” / “define race duration”), it is suggested that students declare who will achieve each action (e.g., “measure” or “check”). Students can decide to delegate each action to just one student, or to two or three of them. They can come back on their declaration at any time. A chat allows synchronous interaction, and the students have to vote to skip to the next phase. With respect to the model, we are here at both the co-construction and co-operation levels. The key idea is that the array denotes the (emerging) adopted organization. Finally, the co-ordination level is the level where each learner is confronted with his tasks: measuring distance or time, calculating speed, applying mathematical procedures, etc. Tasks, rules or roles have been fixed at the preceding level (and learners can come back to this upper-level by a bottom-up transition). At this level, each learner’s work is separated (but coordinated) with that of other learners. In the prototype, the execution level (i.e., enacting the plan) corresponds to a similar interface as when defining and distributing the tasks, but the cells are now editable, i.e., students can edit the calculated values. The interface is still common, allowing everyone to know what he is supposed to do and what the others are doing. The evolution of the solving is dynamically denoted by the fact the content of the chosen cells in organization mode are gradually replaced by effective values with respect to the students’ choices.

A coding scheme to capture organizational issues

The coding scheme (cf. Table 1) elaborated to analyze group-organization (using or not using our prototype) is designed to make salient the dynamic aspects of the organization (changes of levels and breakdown). It is based on the theoretical background (Bardram’s model), our research objectives (understanding organizational issues), and lessons learned from exploratory experiments. For each of the Bardam’s model levels, it proposes 3 items that correspond to some given characteristics of the given level. These 9 criteria are more precisely defined via 2 to 5 indicators (or sub-criteria) each. For example, at the level “co-operation”, the criterion “2.2 Decision-making about the organization” is characterized by four indicators (“allocation of tasks”, etc.).

Table 1: The coding grid

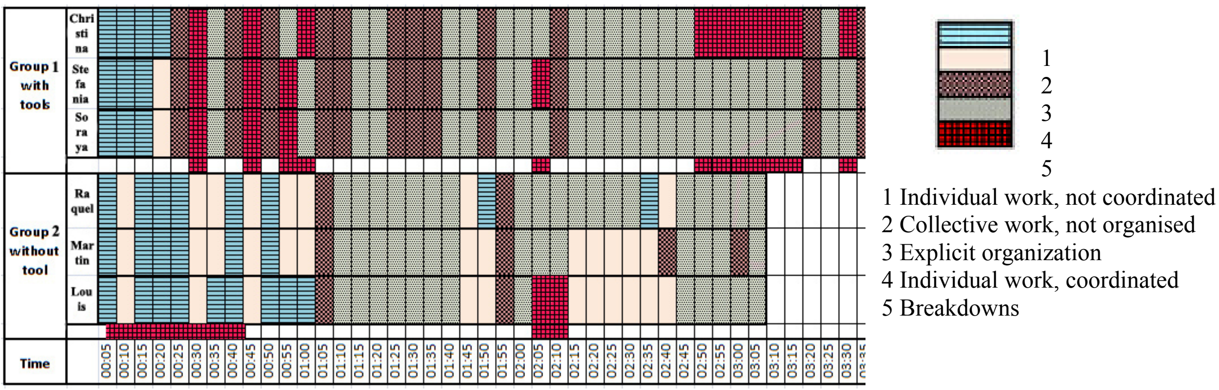
Level	Actions	Sub-criteria / indicators
1 Co-construction	**1.1 Understanding of the problem**	**1.1.1** Working out or improving a common representation **1.1.2** Working out or improving a common language
	1.2 Elaborating or revising a general organization of the resolution	**1.2.1** General planning of tasks **1.2.2** Elaborating/fixing a division of labour **1.2.3** Defining roles **1.2.4** Taking time into account
	1.3 Installing a co-operative structure	**1.3.**1 (Re) Defining general rules of interactions **1.3.2** (Re) Defining resources-sharing and interactions means **1.3.3** (Re) Defining how to use the interaction means
2 Co-operation	**2.1 (Re) Proposing, negotiating a precise planning**	**2.1.1** (Re) Breaking up the plan into tasks and sub-tasks **2.1.2** (Re) Defining the division of labour **2.1.3** Managing results **2.1.4** Managing tasks articulation **2.1.5** Managing tasks schedule
	2.2 Decision-making about the organization	**2.2.1** (Re) allocating tasks **2.2.2** (Re) adopting a division of labour **2.2.3** Making organization explicit **2.2.4** Solving conflicts
	2.3 Agreeing about how to work together	**2.3.1** Deciding on how to evaluate and mutually adjust each one’s work **2.3.2** Being aware of others students’ planned work **2.3.3** Specifying the rules / communication of the results **2.3.4** Specifying the rules / usage of the proposed tools
3 Co-ordination	**3.1 Adjusting the adopted organization**	**3.1.1** Taking collective advancement into account **3.1.2** Articulating tasks **3.1.3** Synchronizing tasks **3.1.4** Requesting organization modifications (votes)
	3.2 Applying the adopted organization	**3.2.1** Applying the adopted tasks allocation **3.2.2** Applying the adopted division of labour **3.2.3** Applying the adopted rules / communication of the results **3.2.4** Applying the adopted management of time **3.2.5** Being aware of one’s tasks
	3.3 Manner of working together	**3.3.1** Being aware of the others’ actions **3.3.2** Evaluating and mutually adjusting one’s work **3.3.3** Complying with the communication rules **3.3.4** Complying with the rules / usage of proposed tools

We define a breakdown as a difficulty or a contradiction related to the organization activity which could break the dynamics of collective solving problem if it seemed likely to remain for some time. Breakdowns must be regarded as natural and important events, which should (if the actors are aware of them) challenge the group, and cause a reflexion on the means or the object of the work, i.e., a bottom-up transition. A breakdown is solved by a stabilization of the object or means of work, and should end-up by a top-down transition. The general structure of the coding grid is thus also useful to detect breakdowns. Our definition of a breakdown is too general to be used as a detection criterion. The coding tool can however be used by considering the negation of the criteria and sub-criteria, reformulated as necessary. For example, the criterion "understanding of the problem" on the co-construction level breaks up into two indicators (or sub-criteria): "to work-out or improve a common representation" and "to work-out or improve a common language". The corresponding breakdown criterion is "problem not collectively understood" and the two sub-criteria are "common representation not clearly established" and "common language not clearly elaborated/acknowledged." Such sub-criteria are not absolute indicators of breakdowns, but should rather be regarded as "symptoms" that may conduct to diagnose a breakdown. Indeed, when considering breakdowns, time is an important issue. When a breakdown is detected, data can be further analyzed to understand if it has been solved and how, or not solved and why.

Exploratory testing of the coding scheme

In order to check if our coding scheme allows interpreting a session in the terms of the model, we have used it to analyze two groups, one using our prototype and the other just using the non-specific means (shared simulation and chat). Every computer was equipped with software (Camstasia) to record the learners' screens in the form of a video file. The chat's and the different tools' logs were also recorded in a XML format. A numerical tape recorder was used to capture possible learners' oral comments if any. Learners' chat messages were copied into an Excel file. Then, by simultaneously analyzing the videos of each student (i.e., 3 videos by group), the different learners' actions, as captured at the computer interface, were coded and inserted in the Excel file. The coding denotes: the timing; the name of the learner; the tool that is used; the type of action (e.g., "measure"); complementary data such as the data value or the tool's mode (organization, execution). The result is a chronological reconstruction of the collective session as a 3 column table displaying the messages and actions of the three learners of a group. Table 2 provides a visual representation of part of the overall coding.

Table 2. The overall result of the coding



Pieces of analysis for Group1 (using the prototype)

After the introduction phase, the "data description" shared editor suggests students to list the data to be acquired for the challenge. This collective phase corresponds explicitly to the co-construction level of the model. Group 1 produced a list of 10 lines. This is an example of collective production as a result of a common representation (sub-criterion 1.1.1; numbers refer to Table1) and development of a common language (1.1.2). The meaningful order of the lines is an example of the elaboration of a general planning of the tasks and subtasks (1.2.1) indicating the beginning of a general organization of the resolution (1.2). Consequently we can clearly qualify this episode (which lasted 1 hour) as corresponding to the co-construction level of the model. This was confirmed by the chat messages analysis (not exemplified here due to space limitation).

After having listed the data to collect and the associated actions, the students skipped to the planning definition/execution editor (indication of the co-operation level), exchanged messages corresponding to an allocation of the tasks (2.2.1) and adopted a division of labor (2.2.2) based on the different lines defined at the previous stage. In this phase appear messages such as: Soraya: "Cristina, you manage 1234"; Soraya: "yes?"; Soraya: "Stefania line 567"; Soraya: "Soraya line 8910". They use the editor to declare that they will manage some lines and/or cells (2.2.1, 2.2.2), making the adopted organization visible (2.2.3). The indicators clearly denote that the students skipped from the co-construction level to the co-operation level. The fact students considered their organization to be sufficient and that they were going to skip to the execution mode was both denoted by messages (e.g., Stefania: "execution?" -co-ordination level indicator- or messages filled automatically by the voting tool like "Student[x] wants to change the mode, do you agree?") and the use of the voting tool to accept the change (indication of transition). The data then denotes the "execution" of the adopted organization. As an example of an interesting sequence that appears at this stage, the students filled 10 selected cells of the table (3.2.1, 3.2.2, 3.2.3) and then adjusted their results (3.3.2) by discussing and finally agreeing on the speed unit to be used: Cristina: "we do it in cm/s? or in m/s?"; Stefania: "Yes"; Soraya: "for what" ; Cristina: "for speed"; Soraya: "m/s"; Cristina: "it is easier in cm/s"; Cristina: "ok? " ; Soraya: "ok". This denotes a move from the co-operation level to the co-ordination level. The students can skip from the "organization" mode to the "execution" mode of the editor and *vice versa*. The data presents six uses of the tool in "organization" mode (total=45 minutes) and six uses of the tool in "execution" mode (total=2h08minutes), this latter being located primarily at the co-ordination level. Moves from the "organization" to the "execution" mode clearly denote top-down transitions (co-operation to co-ordination), and moves opposite to bottom-up transitions (co-ordination to co-operation).

Pieces of analysis for Group 2 (not using the prototype)

Group 2, not having a tool that suggests acting at the co-construction level at first, adopted a different approach. Individual uses of the simulation tools show students began by attempting to solve the problem individually for about 40 minutes. The absence of any organization is (according to our indicators) a symptom of a possible breakdown. The breakdown is confirmed when the data shows that one student decides to share his data with the others, and realizes that there are discrepancies. The students suddenly realize that two of them did not understand the problem: Martin: "there is something I don't understand…" (1.1.1); Louis: "me too." (1.1.1). The breakdown is solved by Raquel's explanations (1.1.1). This breakdown corresponds to the co-construction level, and is solved at the same level. After this breakdown is solved, messages related to the resolution strategy (1.2.1) appear, and then on the division of labor (2.2.2), and then the allocation of tasks (2.2.1), for example: Louis: "to better organize ourselves I make the cars 7 8 9, you share the others it will be quicker" (1.2.1, 1.2.2 and 2.1.2), Martin: "Louis 4 5 6 and me the 1 2 3" (2.1 and 2.2). These messages denote a top-down transition to the co-operation level. The discussion continues at this level, Martin: "each one has to find when they stop, the time length of the various stops ok??"; "Raquel 456"; "ok??"; Raquel: "ok"; Louis: "ok" (2.2). Next, learners start to gather the data and transmit the results when ready. This meets the different 3.2 sub-criteria (application of the adopted organization). It can however be noted that, during these 39 minutes, each learner solves the entire problem and communicates his results in his own language. This corresponds to the co-ordination level, but is rather a set of simultaneous individual activities.

Breakdowns (Groups 1 & 2)

A first example is related to a conflict in the use of the "data description" shared editor (Group 1). In this case, although the editor is meant for the co-construction level, their use of the shared editor is situated at the co-ordination level. A problem appears when they simultaneously modify the same line: Soraya: "so you are going to complete all the table?"; Stefania: "not all". To solve the conflict they carry out a bottom-up transition towards the co-construction level: they agree on the use of the shared tool (1.3.2, 1.3.3), which had not been agreed on yet: Soraya: "only one fills the table"; "and the others correct and add". They then move to the co-operation level to specify how to share the editor (2.3.4): Soraya: "I fill", and then they return on the co-ordination level and continue their work (filling/correcting lines).

We also categorize as breakdowns ignored requests for organization. For instance, in Group 1, at the co-operation level: Stefania: "I finished column 6"; "What should I do?"; "What line?" (no answer). This breakdown is due to a bad synchronization of the tasks, and was solved when the two other students completed their work (6 minutes later). In Group 2 we identified 5 ignored requests for organization, for example: Martin: "everyone must choose 1 car or everyone must choose 3???"; Martin: "I've also nearly finished calculating the final results after so what can you do?; Raquel: "and now what should we do??? ".

An example of a serious breakdown (which impacted the final result) implying the three levels of the model (Group 1) begins at the co-ordination level with the success of a student in testing some values. This brings the group to modify the adopted organization and to redefine the general strategy (co-construction) by a revision of the tasks allocation (co-operation): Soraya: "Cristina you test, we fill the table". Then each one carries out the new organization, two learners filling out the table (co-ordination) while the third tests the values (co-ordination). At a given moment, this latter transmits a message to warn the group (indicator of breakdown 3.2.5): "I'm sorry, I'm unsuccessful"; "I tried but some calculations are wrong I think because I succeed with some cars and not with others". The task allocated to this third student is stopped, while the two others continue their calculus. As the warnings remained ignored, the breakdown lasted for 1 hour, the group not realizing they were facing a serious problem. This led them to fail. It can be noted that, in this case, the students did not make this change of strategy explicit by modifying the current plan description. However, interestingly, the grid helped us understand that, in some other cases, during the plan execution (i.e., in context), students did request to skip back to the organization interface and modify the plan. As an example, one of the students discovered some discrepancies in the measures. She used the chat to suggest there was a problem: Stefania: “Take a close look to the duration of car #1, we have 1 second of variation!!!”; “It’s because of … (the reference point they use for the measure)”; she changed the value, and then they moved to the organization mode; Cristina: “Stefania we take as starting line the white line… or another?”; Stefania: “Or the end?”; Stefania: “The line or before the line”; Soraya:”All the line”; Stefania then proposed to modify the plan (it was one student per line): “We make two per line to compare the variations” and Cristina: “Soraya Cristina line 1” ; Cristina: “Stefania Cristina line 2”; Stefania: “ok”; Cristina: “Stefania Soraya line 3”.

Discussion: Some lessons learned

When using the grid, it appears that some messages or actions may correspond to several sub-criteria; in this case they are coded by the corresponding criterion. It also appears a group of actions and/or messages are to be coded as a single episode in the terms of the model. Finally, unexpected uses of the technology must also be taken into account.

Applying our coding tool to the data collected for the group using the prototype if of course much easier. The prototype and the coding tools being based on the same model, the use of the different functionalities (editors, vote, etc.) provide very precise information with respect to the students’ organisation-level and the transitions, information which is confirmed in most cases by analyzes of the messages and actions. The fact the general structure is very clear (co-construction and then alternated episodes of co-operation and co-ordination) eases the coding and the understanding. For instance, the editor that allows deciding what data is to be collected leads to actions and messages corresponding to the co-construction level. Indeed, elaborating a list of actions via a shared editor leads to working out a common language (1.1.2) and to establishing a mutual understanding of the problem (1.1.1). Addressing the order of the lines is a premise for a general planning of tasks (1.2.1). The fact that the students use the “organization-mode” or “execution-mode” of the planning editor provides an explicit indication of the level to be considered (co-operation, co-ordination), which can be checked using the coding indicators. Skipping from one tool to another, changing mode (organization/execution) or using the voting tool are reliable indicators of transitions, which can be confirmed by the precise actions and messages processed at the same time. For the group without the prototype, the coding is made more difficult as things (actions, messages, levels) are much more intertwined. Coding and understanding what is happening requires locating the messages that can unambiguously be interpreted (e.g., allocation of tasks or division of labour), and to use them to further analyze the rest. For instance, in Group 2, each learner was at the same time solving all the problem and sharing his resolution with the other members. The activity of organization primarily consisted in sharing and checking the individual results. This was based on an implicit organization, which was not directly visible. Many of our sub-criteria did not apply, and were inducing us in error (level-confusions; detection of false breakdowns). We were only able to use our coding tool properly (but, then, with the same effectiveness as for Group 1) after we understood the underlying implicit operating-mode of the students, which was made possible by analyzing longer sequences and by using the coding-scheme criteria rather than the sub-criteria.

Although the prototype has a structuring effect, we discovered transitions which did not correspond to changes of the tool’s usage mode. For example, the students have modified their organization twice (Co-operation) in “execution” mode, in one case without clarifying it in the tool. They also made some measurements (Co-ordination) in “organization” mode. As said previously, Bardram’s levels correspond to analytic distinctions: an activity takes place simultaneously at all levels. However, it would be interesting to go deeply into the question of why the students did not use the tool-facilities. We evaluate to approximately 80% the conclusions from the prototype-usage confirmed by message and action analyses, and to 20% the ones that were contradicted.

The exploratory test also provided some hints related to the structuring impact of the prototype (differences between the groups), which are not described here due to space limitation. Independently from this impact, the fact the prototype eases the analysis and makes it manageable by a tutor (we believe it does not need a coding specialist if pertinently supported by dedicated tools) is, given our objectives, an interesting result.

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Collaboration and abstract representations: towards predictive models based on raw speech and eye-tracking data

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Abstract: This study aims to explore the possibility of using machine learning techniques to build predictive models of performance in collaborative induction tasks. More specifically, we explored how signal-level data, like eye-gaze data and raw speech may be used to build such models. The results show that such low level features have effectively some potential to predict performance in such tasks. Implications for future applications design are shortly discussed.

Introduction

Theoretical background

We present an exploratory study about gaze patterns exhibited during collaborative interaction. We conducted an experiment to examine dyads solving induction tasks. Two tasks were chosen based upon two main criterions which were to require inductive and abstract thinking, which are known to be related to high-level cognitive processes like learning, and to be visual, in order to allow for the detection of potentially meaningful patterns in the eye-movements. Several authors (Genter 1989, Hofstadter 1995) argued that learning may proceed by analogy between multiple examples. Indeed, analogy consists of finding structural similarities between things that may appear as completely different. Thus, it corresponds to extracting abstract structural features of the concerned objects. The same sort of process may occur during conceptual knowledge learning if we consider that learners have to find similarities between examples of a particular concept to finally induce a general and abstract representation of a that concept.

Raven progressive matrices are a typical task which requires induction and the construction of abstract representations. These problems have been shown to be central to all cognitive abilities in the sense that most specific ability tests are generally well correlated with Raven matrices tests (Carpenter, Just and Shell, 1990). Carpenter and his colleagues found that gaze patterns partially reflected the solving phases of these tasks by comparing verbal reports during resolution and gaze data. They have also shown that abstraction abilities are one of the main factors which explain successful solving of the problems.

Schwartz (1995) has shown how collaborating students may outperform individuals in building abstract representations about scientific concepts. He ran two experiments in which students had to build abstract representations of a problem in order to answer a set of questions. He showed that the performance of the dyads were greater than what could be expected from a theoretical model called which he called truth-wins model. This model assumes that the best performance that a pair may achieve is the performance of the best of the two collaborators. This study suggests that this theoretical model may not be valid and that a dyad may be more than the sum of two individuals.

Eye-movements have been related to social interaction processes by several authors. Richardson and Dale (2005) have shown how the language and the gazes are related to each other. They have demonstrated that the coupling between two interlocutors' gazes is correlated with their level of understanding. They found a similarity in the gaze sequence of the conversants with a certain time lag. This effect is explained by the fact that speakers look at the object they are talking about before naming it and listeners do the same after hearing the word (Griffin and Bock, 2000). .

Task selection

We have chosen to explore how dyads solve two different logical games, both requiring induction and abstraction abilities. The first was also studied by Carpenter, Just and Shell (1990), namely the Raven progressive matrices (see Fig. 1 top-left). It consists in finding out the last element of a 3-by-3 matrix which exhibits certain logical patterns over its rows and columns. Performance on Raven matrices is a good predictor for performance on most specific ability tests which are generally well correlated with Raven matrices tests (Carpenter, Just and Shell, 1990).

The second kind of problem is called Bongard problems (see Fig. 1 top-right). These problems were originally designed by M. Bongard in a book entitled "Pattern Recognition" (1970). The goal was to provide examples of what pattern recognition machines should be able to solve. The goal of these problems is to find a common pattern or rule among the six images on the left (examples) and which doesn't work for the six images on the right (counter-examples). What makes these problems quite hard is that the rule may involve completely different features. It may be the relative position of the objects, their relative size, the orientation or it may also be a kind of higher level shape formed by many lower level shapes.

Research questions

This work explores the possibility of building predictive models in order to develop in the future gaze-sensitive groupware. Indeed, we think that eye-tracking techniques will become more and more accessible as it is possible already to build cheap eye-trackers with simple webcams. Our idea is to use real-time gaze data to support the analysis and diagnosis of collaborative learning processes. The main prerequisite to this goal is to find some gaze patterns, possibly combined with other easy-to-acquire data like raw speech, which are related to successful collaboration. Our approach to this problematic is to apply machine learning algorithms. Although these techniques generally do not yield theoretically interpretable models, they enable to build predictive models which can be very efficient and sufficiently fast to be computed in real time.

Method

Task

The two kind of problems described above have been slightly modified for the purpose of this study. In order to make them more interactive, the images have been split between the two participants. For the Raven matrices, six (out of nine) cells were shown to each participant. One saw only the upper-right part of the matrix while the other saw only the lower-left part of the matrix. Thus, they each had three personal cells which were not seen by the other participant and three shared cells (on the diagonal). One of the shared cells was the missing cell which had to be discovered by the collaborators. For the Bongard problem, the split was a bit different. Each participant could see the six counter-examples (right images) but each participant only saw three out of the six examples (left images). Thus, in both cases, three cells were not shared by the collaborators.

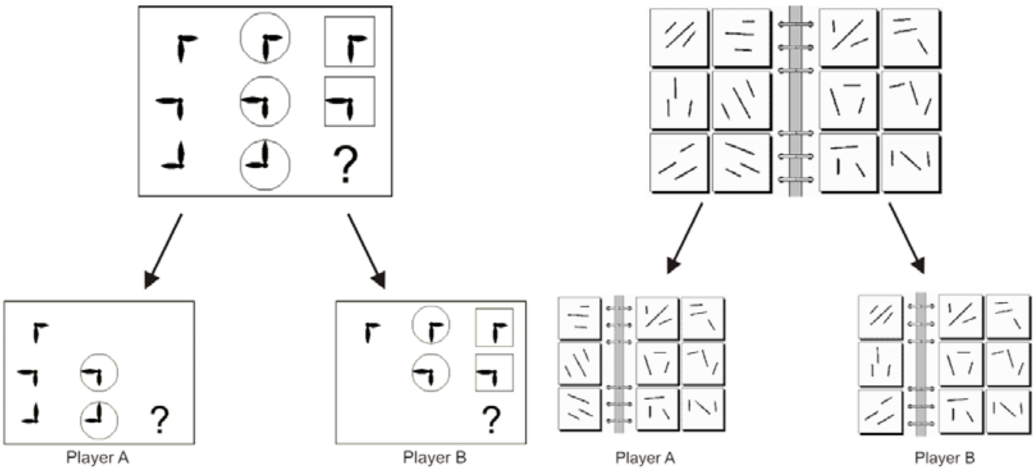

Figure 1. Examples of a Raven progressive matrix (left) and of a Bongard problem (right). The answer for the matrix would be "clock indicating nine o'clock inside a square" as there is a shape progression along the row and a clock rotation along the column. The rule of the depicted Bongard problem would be "the lines are parallels" while there is no rule for the right side. Bottom images show modifications applied to the problems to make them collaborative.

Participants

Nine dyads (ten men and eight women) were recruited among campus collaborators and students. Subjects' ages vary between 17 and 53 with a median of 27 years. None subject was aware of what a Raven matrix or a Bongard problem is before the beginning of the experiment.

Procedure

Two computers were installed in the same room separated by a shelf in order that the subjects could not see each other while still being able to speak to each other. Two eye-tracking screens (Tobii T1750) were used to record subject's eye movements. Subjects were first asked to fill in a short questionnaire about general information like age and sex and how much they know each other. The experiment was composed of 12 static images which could be passed by simply pressing the spacebar at least one time on each computer. The first and the seventh slides were instructions for the Raven matrices problems and the Bongard problems respectively. Slides 2 to 6 presented the Raven matrices and slides 8 to 12 were the Bongard problems. The problems were in order of increasing difficulty in order to allow subjects to familiarize themselves with the problems.

The subjects had to solve the problems together, agree on a solution and then, say it out loud and press the spacebar to go to the next problem. The correctness of the solution was checked and recorded by the experimenter. There was a maximum time limit of 5 minutes for each problem. Speech was also recorded separately for each individual.

Data analysis

Variables

We computed several features based on the gaze data. The first feature, called number of *comparisons*, aims at detecting when subjects compare two cells. We identified every sequence of at least 3 fixations with at least one back and forth movement between one cell and another. The *comparisons* variable is the ratio of all fixations which belong to such sequences (see fig. 2, top-left). A related feature is the *comparison intensity.* For each of these comparison sequences, we computed the number of transitions between the two cells concerned and then, we averaged this number over all comparison sequences (see fig. 2, top-left).

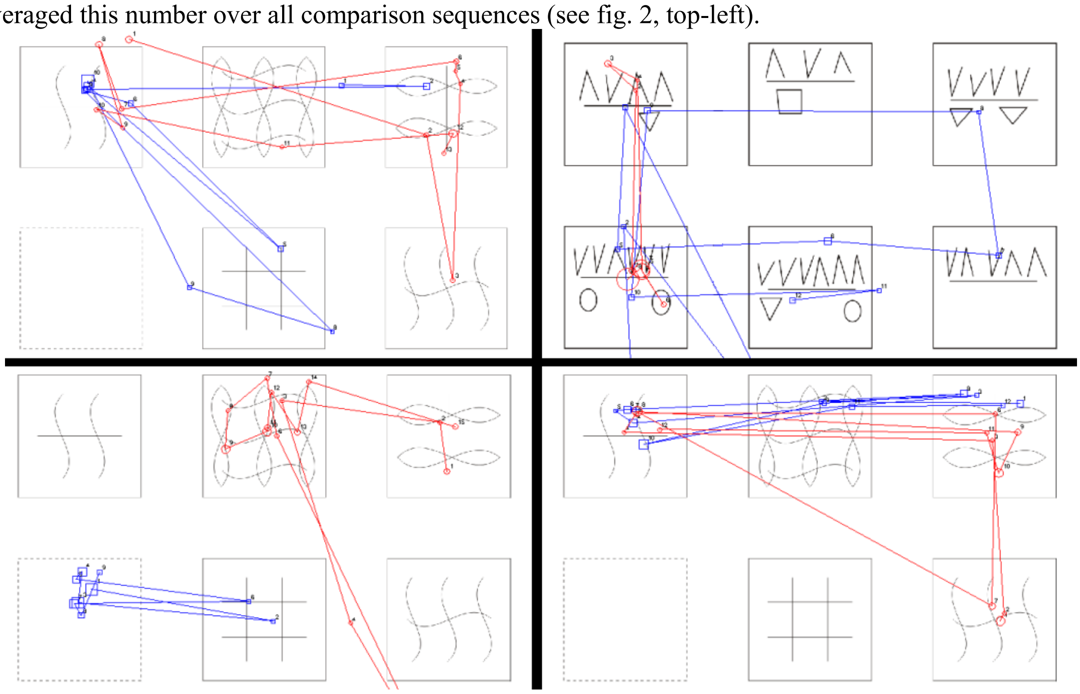

Figure 2. Illustration of gaze features. Top-left picture depicts one subject (square) doing an intense comparison between the upper-left cell and middle cell and the other subject (circle) doing a weak comparison between the upper-right cell and middle-right cell. On the top-right picture, we can see a dispersed subject (square) and one not dispersed (circle) Bottom images illustrate high gaze divergence (left) and low gaze divergence (right)

Another feature measures how much subjects look at all cells in an equivalent manner or in other words, how much their gaze is dispersed. For this, we aggregated the fixation durations in a matrix, called *cell density matrix*, representing the nine cells present on the screen and then for each cell, we took the ratio of the total aggregated durations. Finally, we computed the standard deviation of the values in this matrix as the *gaze dispersion* value (see fig. 2, bottom-right). We also used the cell density matrix to compute a dual gaze feature called *gaze divergence* (see fig. 2, bottom-left). This feature is simply the cosine between the density matrices of both subjects, which is a way to assess the similarity between two matrices.

Each second of the recorded speech data was automatically labeled as *speech* or *no-speech*. First, the audio file was split in order to have one fragment per problem and each fragment was normalized using the minimum and maximum found over the sample. Then, the root-mean square was computed for every second and if this value exceeded a threshold of 0.4, the second was considered as *speech*. The resulting feature, called *speech time*, is the ratio of seconds labeled as speech for each subject. Then, we also computed the difference of the *speech time* between the subjects of a pair in order to have an estimation of the *speech time asymmetry*. We decided to focus only on these simple raw measures of speech because it is fully automatic and thus it could be easily used in potential future application.

Finally, we analyzed two dependent variables: the success at a particular problem and the *solving time* for correctly solved problems.

Analysis methods

We tried to apply machine learning algorithms on our dataset in order to see if it is possible to predict the performance of individuals by using the gaze and speech features described above. Indeed, one of our final goals is to build gaze-sensitive applications that would detect in real-time meaningful gaze patterns, possibly combined with raw speech features, in order to give feedback to the users. Thus, machine learning techniques provide with a way to build models able to do such detection.

In this study, we compare the use of two different machine learning algorithms, one called J48, which builds binary decision trees and another called Naïve-Bayesian, which estimates probability distributions for each features.

Results

We present here results which stem from the use of two machine learning algorithms (Binary decision tree or Naïve Bayesian classifier) for each problem class separately but also for both problems classes without distinction. We also analyzed the effect of using speech only as predictors, gaze only or gaze and speech combined. Two values are always reported, the number of correctly classified cases and in parenthesis the kappa statistics, which represents how much the model is better than chance. These values have been obtained using 10-fold cross-validation procedure. Algorithms were fed with features computed on one minute duration and the minute was also used as a predictor. However, we discarded for each problem the last minute before the solution was announced in order to avoid the effect of speech which may due to the explanation of the solution. The predicted variable was the outcome of the problem: solved or unsolved. The predictors were the number of comparisons, the comparison intensities, the gaze repartition and the gaze divergence for the gaze features and speech quantity and speech asymmetry for the speech features. It is important to note that these two algorithms, like most machine learning, do not necessarily produce better results when more predictors are given.

Table 1: Results of the machine learning algorithms for both problem classes combined, kappa’s are in parenthesis

	Naïve Bayesian classifier	J48 Binary decision tree
Gaze + speech	78% (50%)	79% (51%)
Speech only	77% (45 %)	86% (65%)
Gaze only	74% (35%)	68% (10%)

First, it is very interesting to note that we can obtain quite good results (50% above chance level) while we are trying to predict success in two different tasks. This is very encouraging as it suggests that there may exist some patterns in gaze and speech which are task independent. Of course, the two tasks are not completely different as they both imply some similar processes (induction and rules abstraction). We can also see that at this level, speech plays clearly a larger role than gaze. Indeed, we see that models using only gaze features are the worst for both algorithm types. However, for the Naïve Bayesian classifier, gaze seems to slightly improve the performance compared to speech only, indicating that it can still play a role.

Table 2: Results of the machine learning algorithms for Raven problems, kappa’s are in parenthesis

	Naïve Bayesian classifier	J48 Binary decision tree
Gaze + speech	78% (56%)	91% (81%)
Speech only	78% (56%)	91% (81%)
Gaze only	68% (32%)	68% (34%)

The results concerning Raven problems (see table 2) only are surprisingly high, producing up to 80% above the chance level with 91% of correctly classified instances. Moreover, we can see that these results are explained only by speech features. Although it is a bit disappointing because we expected to find some patterns in gaze data, it is also very surprising to see that such raw speech features may predict so well the success on these problems. Of course, we must be very cautious in interpreting these results because like for a correlation, it does not imply that there is causality between speech quantity and asymmetry and the success.

For Bongard problems (see table 3), the situation is the opposite than for Raven problems, although the results are much lower than for Raven and even lower than for both classes combined. This suggests that the good result for all problems taken together is mainly explained by the Raven problems. However, there are still some results for Bongard problems and interestingly, we can see that these performances are explained mainly by gaze features, as the best models are achieved by taken only gaze features without speech features.

Table 3: Results of the machine learning algorithms for Bongard problems kappa's are in parenthesis

	Naïve Bayesian classifier	J48 Binary decision tree
Gaze + speech	76% (34%)	75%(25%)
Speech only	76% (29%)	75% (21%)
Gaze only	77% (37%)	77% (37%)

We also tried to apply these algorithms with slightly different data to have situations closer to a real-time situation. When using only the first two minutes of solving, the results are either similar to those presented or a little bit (3 or 4%) lower. These results are maybe even more interesting because they suggest that it could be possible to detect after one or two minute if the pair will succeed or fail. Moreover, we also tried to predict the success in the next minute. Here, the results are clearly lower than the previous ones but they are still sufficiently high to be considered. We obtain kappa-scores of 40% (instead of 50%) for both problems combined. Again, such results are still more interesting for a potential future gaze-sensitive application because we could be able to predict the moment at which a pair will succeed. Also, it suggests that there exist some phases in the solving processes which are distinguishable by using the gaze patterns and this is consistent with the results found using usual statistical methods.

Discussion

It is very encouraging to see how well machine learning algorithms performed on these data. As we have seen, we can predict up to a certain point problem solving outcomes by using only raw measure of speech and gaze features. Moreover, we see that we may be able to predict the moment of resolution one minute before it happens. These results have great implications as they tend to prove that it is possible to build gaze-sensitive applications, possibly combined with simple automatic speech analysis, in order to provide meaningful feedback to users. Obviously, predicting only the solving moment or the solving outcome is not sufficient for such application but it shows that patterns may exist in gaze and raw speech and thus, we can imagine that similar patterns could be also present in other situation that may be of interest for feedback. However, one must note that gaze plays a significant role only in the Bongard case, while for Raven matrices, only speech was useful for predictions.

Of course, all these results must be taken with care. Indeed, the number of subject is very low and so, it is difficult to generalize. At this point, we cannot be sure that these models built by machine learning algorithms are really universal or if they are specific to this set of subjects.

Conclusion

We have shown that it may possible to design fully automated systems able to predict some outcomes of interaction by using signal-level features like raw speech and gaze data. This is a step towards building applications which may enhance the collaboration processes by providing real-time meaningful feedbacks. This is especially interesting because these problems require high-level thinking and thus, it suggests that similar results may be found in other high-level tasks, like collaborative learning. Of course, these results are only preliminary and we need further before being able to draw strong conclusions.

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From meaning making to joint construction of knowledge practices and artefacts – A trialogical approach to CSCL

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Abstract: CSCL research is often closely connected to dialogic theories of learning and human cognition with an emphasis on shared meaning making. Without neglecting this viewpoint we give reasons for an alternative framework. We call this alternative a "trialogical" approach; it emphasizes joint and organized work with artefacts and practices as a basis for collaborative learning. The paper explains the use of this notion and clarifies theoretical backgrounds for the approach in line with the knowledge creation metaphor of learning, and relates it especially to knowledge building and socio-cultural and cultural-historical theories of human cognition. Various theories concerning mediation are briefly analyzed. The paper also explains how dialogues and trialogues are close to each other if, for example, the role of common ground is analyzed further. Lastly, design principles of the trialogical approach are concisely described.

Introduction

It appears that throughout its relatively short history Computer-Supported Collaborative Learning (CSCL) has aimed at defining its paradigmatic starting points (see Koschmann 1996, 1999, Koschmann et al 2002; Stahl et al 2006). This is not surprising because CSCL has been an emerging research field which is clearly connected to novel ways of understanding fundamental epistemological, methodological, and also ontological questions concerning human cognition and activity. CSCL is married to basic conceptions of the socially, materially, culturally, and technologically distributed nature of human cognition. Yet there are different interpretations how these challenges and possibilities are interpreted, and which broader research traditions provide as a background for CSCL research (e.g., neo-Piagetian framework, a socio-cultural approach, situated cognition, knowledge building).

One very prominent candidate for providing the foundations for CSCL is closely connected to dialogic theories of learning and human cognition, and interactional or shared meaning making (Koschmann 1999; Stahl et al 2006; Wegerif 2006; Suthers 2006). This is a quite appealing approach for understanding the basics of CSCL. It seems, at least in general terms, to fit nicely to many approaches important in the CSCL tradition, such as Bakhtin's ideas of multiple voices (Koschmann 1999), inquiry processes with question and answers (e.g., Muukkonen et al 2004), argumentative skills (e.g.. Andriessen et al 2003), or more general skills of communication and dialogues (Wegerif 2006). In more general terms, this can be connected to the idea that human cognition is mediated by tools (especially by technology) and by signs (Vygotsky 1978). Sign-processes are usually interpreted as fundamentally dialogical (see Wertsch 1991; also Peirce 1931-1958).

There are clear differences how the dialogic approach is interpreted within the CSCL tradition. For example, Wegerif (2006; 2007) makes a clear separation of the dialogic approach from the dialectic (and Vygotskyan) tradition whereas Koschmann has interpreted them more in line with each other (Koschmann 1999). Still, dialogic theories have been seen to provide a basis for CSCL because they lay a foundation for understanding meaning making involved in collaborative discussions mediated by computers.

Despite strong arguments to support the claim that the dialogic theories and meaning making form a basis for CSCL, the present paper is focused on developing a different way of considering the foundations of CSCL; we develop on object-centered, trialogical approach to CSCL that appear to bring issues different from the dialogical approach to the foci. The argument is not that the importance of meaning making and dialogues should be neglected, but rather that is should be supplemented with approaches emphasizing joint work with artefacts and practices. In this paper we aim at giving theoretical reasons and background for this kind of a shift towards, what we call, a "*trialogical*" emphasis of CSCL, and shortly explain our own work with this emphasis. We do not, however, see dialogical and trialogical approaches are mutually exclusive but examine a continuum from dialogues to trialogues.

From the knowledge-creation metaphor to trialogues

We have previously maintained that it is useful to differentiate a *knowledge-creation metaphor* of learning as a third main metaphor for learning as a supplement to Anna Sfard's distinction between the *acquisition* and the *participation* metaphors of learning (Paavola et al 2002; Paavola et al 2004; Hakkarainen et al 2004; Sfard 1998). The idea has been that there are different theories of collaborative work and learning which, despite their clear differences, have also a common aim of explicating collaborative processes of creating or developing something new. As representative theories of the knowledge-creation metaphor we have ourselves analyzed especially Bereiter's knowledge building (Bereiter 2002), Engeström's expansive learning (Engeström 1987), and Nonaka & Takeuchi's organizational knowledge creation (Nonaka & Takeuchi 1995). These theories have clear affinities to theories representing the participation metaphor of learning but still have a different focus especially when directed to processes clarifying collaborative or distributed creativity. The knowledge-creation metaphor is not meant to be a theory of collaborative learning but more like an umbrella term (or a meta-theoretical conception) highlighting underlying similarities across otherwise quite different theories and approaches to collaborative learning and work. We think that it is useful to point out similarities and fruitful tensions between these theories.

On the basis of these theories representing the knowledge-creation metaphor we have tried to analyze what can be learned for developing central aspects of collaborative learning further. From this analysis we have proposed the term 'trialogical' (or 'trialogic') to refer to those processes where people are collaboratively and systematically developing shared, concrete "objects" together (Paavola & Hakkarainen 2005). The basic idea of trialogues is that "objects" (conceptual or material artefacts, practices, ideas) are brought to a more central role than in many traditional theories of human learning. It can be maintained that if the focus is on how people jointly develop and create such 'objects', many dichotomies connected to the learning theories must be thought anew; for example, both individuals and social processes must be taken into account, and both conceptual artefacts and practices are important. We think that theories representing the knowledge-creation metaphor are just aiming at finding ways of overcoming these kinds of dichotomies to understand the dynamics of collaborative creativity.

In trialogues, the interaction through "shared objects" that are in the process of being developed is emphasized (see Figure 1). These objects of inquiry can be knowledge artefacts, practices, ideas, models, representations, etc. but understood as something concrete to be developed collaboratively. These objects or drafts of objects have a prominent role in the interaction (so it is an interaction between subject(s), other subjects, and "objects", not, for example between subjects). The temporal dimension is also important in trialogues in terms of the shared objects being developed and modified iteratively; novelty and innovation emerge only through sustained processes. The objects being developed are meant for some subsequent use and/or potentially to be modified later on. This anticipation of use provides criteria to modify the object collaboratively. In trialogues the object is something concrete (even ideas and conceptions must be externalized to be shared and developed) but at the same time it is something in the process of being developed (cf. epistemic artefacts – Knorr-Cetina 2001). Trialogues mean, then, those processes where things are developed collaboratively; there is not just work with static objects. The emphasis is on developing something new collaboratively, not repeating existing knowledge.

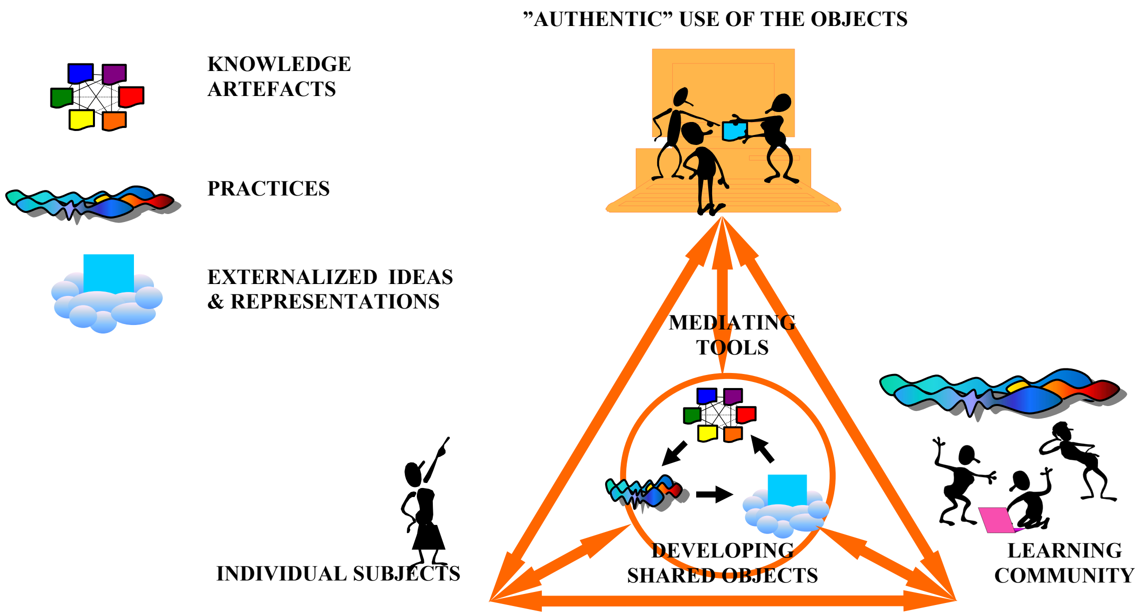

Figure 1. An illustration of the trialogical approach to learning presenting some of the basic elements of it.

One important background for the trialogical approach is the *knowledge building* approach. Knowledge building derives from Karl Popper's (1972) idea of three "worlds" as a basis for understanding human epistemology. According to this, human beings are special in being able to produce cultural or conceptual artefacts which are something different from mental processes within human brain or head, or material things. Carl Bereiter and Marlene Scardamalia (Scardamalia & Bereiter 1994; Bereiter 2002) with their colleagues have developed this approach very systematically to emphasize a joint idea improvement by students supported by specialized technology for knowledge building.

Knowledge building can also be interpreted as a form of a trialogical process although our own interpretation of trialogues emphasizes more the role of practices and material aspects of artefacts than is the case in knowledge building (Hakkarainen, in press). The strength of knowledge building is that it emphasizes so emphatically ways of organizing students' work for collaborative idea improvement. But the cost is that it easily loses sight of more "mundane" practices and processes, and also of the ways that conceptual artefacts must be material and concrete to be shared and developed collaboratively. Knowledge building has leaned heavily on Popper's epistemology with three "worlds" (material, mental, and cultural/conceptual), but we think that broader, and also more elaborate epistemology would be provided by Charles S. Peirce's sign-theoretical approach. In this kind of a Peircean approach three "categories" (ideas/qualities – actual things – mediation/conceptions) are intertwined, and the meaning of conceptions is closely related to practicalities and "brute" happenings of the world (Peirce 1931-1958). Without going in any detailed arguments, we think that Peirce's and Popper's epistemology are closely related (see Skagestad 1993) but Popper's epistemology easily creates a conceptual "world" which is too separate from other aspects of reality.

Another central background for the notion of 'trialogues' is the socio-cultural theory, and the *cultural-historical activity theory*. The cultural-historical approach builds on the idea that human activities are mediated by artefacts, used and modified by succeeding generations of human beings and grounded on practical, everyday activities (Cole 1996, 108-110). Praxis, or practices, and cultural artefacts are developed in interaction with each other in historically situated and evolving processes (Miettinen & Virkkunen 2005). Human activity is "object-oriented" which means that also collective activity has an object of activity (related to the "motive", or to the concrete outcomes of that activity) which characterizes how activities are, in general, understood or explained (Engeström 1987).

This is in line with Marx Wartofsky's (1979) historical epistemology according to which structures that constrain and guide human perception and action are not universal and unchangeable – as assumed by Immanuel Kant – but products of human history, being continuously created and transformed by human beings. According to Wartofsky modes of cognitive praxis are subject to historical development. The central idea is that epistemic artefacts profoundly change the nature of humans' epistemic activity in general, and learning in particular, so that "artifact is to cultural evolution what the gene is to biological evolution" (Wartofsky 1979, p. 205). Wartofsky separated different levels of artefacts; *primary artefacts* are tools and practices directly used in human labour and other activities, *secondary artefacts* are "symbolic externalizations" or "objectifications" of primary artefacts; and *tertiary artefacts* that mediate relations between primary and secondary artefacts and no longer have a direct representational function but represent visions, anticipated changes and possibilities that may be used to change the world. Wartofsky also maintained that these artefacts are not in the mind as mental entities, but are externally embodied in socially shared practices, social organizations, and culturally shared ideas.

The notion of "trialogues" owes, then, a great deal to socio-cultural and cultural-historical theories about human cognition. We think, however, that trialogical processes of knowledge creation can be and have been developed within many research traditions (without necessarily using the term "trialogues"), so the meaning of these processes should be seen across various research traditions. Trialogues concern those processes where people organize their work and creativity for developing some concrete (material and conceptual) artefacts and/or practices together for some subsequent use by developing various versions of the artefacts and/or practices often in long-term processes. According to Knorr-Cetina (2001) the work with *epistemic objects* and *epistemic practices* more and more characterizes modern knowledge work. Epistemic objects or 'epistemic things' (Rheinberger 1997) are knowledge objects which are in the process of being defined, and more open-ended than traditional 'objects' (typical examples are objects investigated by scientists which are often in the process of being defined as the end result of the investigations, but there is no "end" point for these future oriented processes). Similarly practices have been traditionally defined as recurrent processes and rule-based routines but modern epistemic practices challenge this viewpoint (see also Miettinen & Virkkunen 2005). Knowledge-centered work requires a more dynamic, creative, and reflective notion of practice. We maintain that these processes with epistemic objects and epistemic practices are trialogical processes.

The term of '*object*' or '*shared object*' is used in this paper in a theoretical sense. Objects or object-orientedness of human activity has aroused a lot of discussion lately, especially within activity theory

(Kaptelinin & Miettinen, 2005; Engeström & Blackler, 2005; Miettinen, 1998). For us, object-orientedness gives an important perspective on learning and the design of educational settings also outside the framework of activity theory. We are applying ideas of object-orientedness from activity theory more generally in order to build a framework where collaborative work with shared objects is emphasized as a potential design principle of educational practice. Shared objects can then be knowledge artefacts (papers, models, plans), or practices which are developed iteratively together. In the "trialogical" sense the notion of an 'object' comes close to epistemic objects defined by Knorr-Cetina (2001), and is related to at least two basic meanings of the term also in a colloquial speech. Objects have concrete, thing-like characteristics but they are also something to which actions are directed (cf. Engeström & Blackler, 2005). "Trialogical objects" are those thing-like practices or artefacts which people are jointly modifying or versioning, but in order to understand the process of developing these "trialogical objects" it must be understood to which purposes and by which means they are produced. By paraphrasing Peircean semiotics: there must be also at least "final objects", which are giving guidance to the process (not "final" in an absolute sense; also these final objects are changing; but towards which the activity is directed). As an example: if people are jointly modifying and versioning a research paper (which is then a trialogical object) they have some ideas of what it should look like (about its structure and content, etc., that is, about its "final object").

We are *not* maintaining that theories and approaches mentioned above are an exhaustive list of theories analyzing trialogical processes. For example, Papert's constructionism (Papert & Harel 1991) comes close to many aspects emphasized in trialogues(1). Constructionism emphasizes people as active constructors of their knowledge (similarly to constructivism) but not so much construction of mental models (or related things) but things of the real world, usually co-designing something tangible (like building LEGO/Logo). Instead of "instructionism" (and transmission of knowledge) it focuses on constructionism, and more long-term work with meaningful products. Resnick (1996) has introduced the term distributed constructionism to highlight constructionism with things that are seen important in distributed cognition, like collaboration and the use of technology to support constructions. We see these as ways of enlightening different kinds of trialogical processes. Above are mentioned mostly those theories which have influenced our own conception of trialogical processes.

If trialogical processes are treated in many approaches, why to name them with a new term?(2) Is there anything novel here? We think that it is important to emphasize the meaning of these kinds of processes, and to develop ways of analyzing and supporting them. These processes are easily neglected and especially an interaction between various processes supporting trialogues are not seen (for example, work with knowledge artefacts and practices) when CSCL approaches are developed. In this sense it is useful to see similarities and differences within various theories concerning mediation or mediated activity, like Popper's theory of three worlds, Peirce's sign theoretically and pragmatically oriented theory, and Vygotskyan tradition (socio-cultural and cultural-historical theories) with the aim of developing them further (cf. Engeström 1987, 37-73). We have tried to give above some hints of potential re-evaluations from the perspective of "trialogues". Popper's (and Bereiter's) cultural or conceptual artefacts could be interpreted more closely related to practices and material things. Peirce's sign processes can be interpreted more like joint work with external artefacts in culturally embedded processes. Vygotsky (1978, 40) maintained that human beings can control their behaviour as if outside (i.e. culturally) by the means of signs and tools which mediate human activity. In trialogical processes these mediating elements are artefacts and practices which can be taken to be jointly constructed and developed (see Miettinen & Virkkunen 2005; 2006).

One paradigmatic example of a trialogical work process is the way joint research articles (as shared "objects") are produced in successful, collaborative processes. Often one person has the most central role of organizing the work and producing the basic parts of the text, but in successful cases, other writers can add and modify important parts of the text, so that in the end it is not easy to remember exactly who has produced which part of the text. The article itself, or more specifically, drafts of this article have an important role of organizing the work and suggesting and constraining how to continue to modify and develop it. Sometimes two (or more) persons have so much common ground and overlap in their research interests that they can create a joint research paper on the basis of their previous texts without knowing in detail who has been responsible for producing which part of the text but the text itself instigates new ideas. There are many things that influence to the good result; agreement and trust on each others working practices is central part of these kinds of processes, as well as feedback from persons outside.

Another example is from the working life context when activities or routines are taken as a joint object of inquiry to be developed (Engeström 2001; Miettinen & Virkkunen 2005). This requires the use of various kinds of models and concepts but the object of inquiry in these cases is the practices and activities, not conceptual artefacts as such.

From dialogues to trialogues

We think that it is important to see a continuum (theoretically and practically) from dialogues (and meaning making) to trialogues (collaborative work with shared objects). Dialogic theories typically emphasize such things as communication skills, expressions of different perspectives, having multiple voices, sharing meaning, providing shared understanding. Trialogical processes seem to require extra efforts from people (even more than dialogues). Trialogues require usually dialogues, that is, negotiations on meanings, commenting, discussions, etc. Sometimes it is hard to make a distinction between the two. Still, the differences between these two should be seen and analyzed.

One fundamental problem and challenge (also a theoretical problem) emphasized in dialogues is how human beings are able to focus on certain issues with their multiple voices, perspectives and languages, or how they can reach mutual understanding (see Arrighi & Ferrario 2008) . One answer (or an outline for the answer) is provided with the notion of *common ground*. In order to ensure communication people must have ways of grounding and providing common ground for their dialogues, that is, to have some degree of shared history or knowledge in common to ensure that they are not talking about totally different things or using language with totally different meanings (Clark & Brennan 1991).

Peirce already emphasized in his theory of signs that signs and dialogues are not understandable without such common ground or "collateral observation".

> "The universe must be well known and mutually known to be known and agreed to exist, in some sense, between speaker and hearer, between the mind as appealing to its own further consideration and the mind as so appealed to, or there can be no communication, or 'common ground,' at all." (Peirce 1931-1958, 3.621; see also ibid., 6.338; 8.179)

Peirce emphasized the use of indexical signs which refer to some existing or actual happenings or objects (in real or fictional world) common to those who are in dialogues with each other to convey any meaning (Peirce, 1931-1958, 8.112).

Arrighi and Ferrario (2008) have emphasized that human beings very often correct and reshape the common ground during conversation. This happens by taking extralinguistic aspects into account while interpreting each other's sentences or utterances. People are interpreting utterances, and constructing their common ground intersubjectively (by negotiating on meanings), and by being in interaction with their environment (ibid.). Common ground is not something static but in the process of being negotiated in relation to (indexical) features of the environment.

Arrighi and Ferrario relate this approach to Donald Davidson's ideas about triangulation as a basis for human cognition and knowledge. Davidson (2001) maintains that epistemology should be built on a model where subjectivity, intersubjectivity and objectivity are inseparably linked (in contrast, for example, to the Cartesian epistemology which starts from a quest for subjective certainty). Knowledge of other minds, knowledge of our own minds, and knowledge of the world are mutually dependent, and cannot be reduced to each other. It means, for example, that if we are aiming at understanding the meaning of words, or how signs are used, we cannot start from "objective" meanings of words and signs, nor from subjective meanings, or not even intersubjective or cultural meanings but fundamentally from a dynamic theory where subjective meanings, intersubjective aspects, and objective facts and happenings are all taken into account.

A bit similar broadening of the notion of common ground is provided by the approach of "anchored discussion" (Van der Pol 2007). Online discussion can be supported by anchoring it to study material or documents which are the topic of the discussion. So instead of having more commonly used threaded discussion, grounding is made easier by having tools where study materials and documents to which discussion is referring is available on the screen, and annotations and notes can be pointed to specific parts of the documents (ibid.).

These approaches to dialogues where the role of constructing common ground with Davidson's frame of triangulation, and anchored discussion with indexical relations between discussions and study material being discussed come very close to the ideas of trialogues, as also noted by these authors (Arrighi & Ferrario 2008, 82; Van der Pol 2007, 127). The difference is that in trialogues the central aim is not to enhance dialogues but the common ground is provided by jointly constructing external representations, practices and artefacts (dialogues can, of course, help here). In trialogical processes the common ground is deepened (and provided) by modifying those artefacts and practices ("shared objects") which are objects of joint activity. In trialogues we are not interacting only with words or concepts (emphasized in dialogues) but also modifying conceptual artefacts, external representations, and practices. We are (or can be) both indexically and symbolically attached to the shared objects. Participants of joint activity do not need necessarily to have complete agreement or shared understanding of these shared objects (which is the same with the common ground in general), but these shared objects provide a concrete reference point which can then be collaboratively modified and clarified during the process.

Another way of “broadening” dialogues towards trialogues, or seeing this connection, is to use inquiry models or question-answer processes as a starting point. The interrogative model of inquiry conceptualizes epistemological processes as question-answer steps (Hintikka 1999; Hakkarainen & Sintonen 2002). Human beings (as inquirers) acquire knowledge by putting questions to other humans or to the “nature”. According to this formulation, also nature can provide answers to questions provided by the inquirer, for example, with experiments. These formulations capture an important basis of epistemology for inquiry processes. We think, however, that this kind of a framework should be broadened if conceptions about distributed cognition are taken into account; and this is a way of coming close to the trialogical processes (Paavola et al 2006). The distributed approach means that the role of external artefacts and practices frame the way how people are putting questions and giving answers during the process of inquiry. Existing artefacts (theories, models, methodologies, etc.) and practices give elements and basic means for the question-answer steps, and usually the aim is also to modify and frame novel artefacts and practices during the process.

Instead of having a “game” with two players (either the inquirer(s) and nature, or the inquirer and a community) the basis for trialogues is then a model with three players: an inquirer (making questions, giving answers, or interpreting), “nature” (i.e. the target of the research including artefacts and practices), and a community (making questions, giving answers, or interpreting) (cf. Pera 1994). Inquirers are making inquiries about nature with other inquirers but at the same time using and producing cultural or conceptual artefacts. The inquiry process happens in trialogues through developing these mediating artefacts and practices.

Similarly sign processes can be interpreted anew from the trialogical perspective if it is taken into account that human beings are able jointly to produce external representations and signs to be re-interpreted by others (see Skagestad 1993). We are not just interpreting signs but also producing signs as external representations with others to be interpreted and modified in the future.

The line between dialogues and trialogues, and similarly with the participation and knowledge-creation metaphors of learning, is not, then, absolute. If people are, for example, producing a joint research paper, the trialogical work with the text and dialogical commenting and discussion about it intertwine a great deal. Still there is a clear difference in the emphasis with these two basic frameworks.

The trialogical approach can be used as a heuristic tool to highlight certain aspects of collaborative learning and work. The aim can be to transform existing practices of learning from “monological” (starting from individualistic learning), and “dialogical” (highlighting such things as participation to expert like practices, communication, dialogues) towards more trialogical ones (joint work around shared objects and practices supporting this work). How and if these transformations are possible is a practical question concerning pedagogical practices but also a theoretical question concerning ways of conceptualizing the aims and means of human learning and cognition in general, and within particular pedagogical models. We have maintained, for example, that the *progressive-inquiry model* (Hakkarainen 1998; Muukkonen et al 2004) developed in our research group has been transformed from having aspects from the acquisition perspective (emphasizing conceptual problems, and conceptual scaffolds) towards the participation perspective (emphasizing social and cultural aspects and practices supporting inquiry processes). Currently, we are struggling to understand progressive-inquiry learning as a form of trialogical activity focused on practices of collaboratively advancing a shared object of inquiry, whether it is a research problem, theory, plan, product, practice (to be transformed), or project. This endeavor requires theoretical and conceptual development and corresponding improvements of research methods and methodologies in line with the trialogical approach.

Affordances for trialogical technology

A trialogical approach puts joint work around knowledge practices and knowledge artefacts to the front. This framework has profoundly affected by the emergence of ICTs that transform intangible ideas to shareable digital artifacts. What kind of role does such epistemic technology play in trialogical processes? Human beings have taken part in activities which can be interpreted as trialogical since the beginning of their very history (Donald, 1991; Vygotsky, 1978). By relying on conventional writing, visualization, and manufacturing instruments, they can develop knowledge artefacts and practices jointly and systematically. Yet, when addressing information and communication technologies, investigators have for long emphasized (as the term itself says) either information genre or communication genre with monologues and dialogues as respective social activities (Enyedy & Hoadley 2006). Further, theories on knowledge creation have not paid sufficient attention to the role of epistemic technologies in human activity.

While advancement of open-source development communities, for instance, highlight potentials of ICTs to facilitate collaborative or distributed creativity in the trialogical sense, ICTs have too often been addressed as something that either allows delivering study materials or opening up networking and communication possibilities. The success story of Wikipedia is also strengthening the belief about the influence of new technology in knowledge-creation processes. Such approaches can be interpreted as forms or at least nearby phenomena to trialogical processes. Trialogical activities are supported by appropriate technologies that help the participants to create and share, elaborate and transform, organize and visually model diverse epistemic artifacts in conjunction with making visible, reflecting on, and transforming knowledge practices. Technology as such is no guarantee of trialogicality but it can give affordances for fluent and organized joint work with knowledge artefacts and practices. As we see it the trialogical approach requires that theoretical ideas, novel pedagogical practices, and technology development are developed together; these changes go together. Also outside the CSCL community (and related communities making research on collaborative technology) the role of technology to enhance distributed creativity is more and more recognized (e.g., Miettinen 2006).

In a large, five-year (2006-2011) EU-funded *Knowledge-Practices laboratory* (*KP-Lab*) project, the aim is to develop technology to support forms of trialogical learning (*http://www.kp-lab.org*). Theoretical conceptions of trialogical learning have provided directions and ideas for transforming existing pedagogical practices towards more trialogical knowledge practices, and for developing related technology. Basic characteristics of trialogical learning were defined at the beginning of the KP-Lab project. They were formulated on the basis of analyzing basic features in theories representing the knowledge creation metaphor of learning (Paavola et al. 2004), and using previous experiences of developing learning environments, and in relation to pedagogical aims of the project. The knowledge creation metaphor of learning transforms many old dichotomies concerning learning theories, such as individual vs. community, concepts vs. situations, theory vs. practice (ibid.). The following *design principles* (DPs) were then formulated characterizing the general features of the trialogical learning:

DP1) *Organizing activities around shared "objects"*: A central idea of trialogical learning is that work and learning are organized around developing shared, concrete objects, that is, conceptual artefacts (e.g., ideas, plans, models), concrete, material products (e.g., prototypes, design artefacts) and/or practices (e.g., ways of working in higher education).

DP2) *Supporting interaction between personal and social levels*: People integrate their own personal work and group's practices and resources for developing shared objects, combining participants' expertise and contribution into the shared achievement.

DP3) *Eliciting individual and collective agency*: Trialogical learning has its basis on epistemic agency of the participants; both agency of individual participants in their own efforts, but also collective agency supporting social processes and collaborative efforts. (This design principle comes close to the previous one, and was actually merged to it in later lists of design principles).

DP4) *Fostering long-term processes of knowledge advancement*: Trialogical learning requires sustained, long-standing work for the advancement of the objects of inquiry.

DP5) *Emphasizing development through transformation and reflection between various forms of knowledge and practices*: An interaction and transformations between tacit knowledge, knowledge practices, and conceptualizations are a driving force in processes of knowledge creation.

DP6) *Cross fertilization of various knowledge practices across communities and institutions*: Knowledge work in KP-Lab engages people in solving complex, authentic problems and producing objects also for purposes outside the educational institution; An essential aspect of the KP-Lab project is hybridization between schooling/studying and research cultures as promoted in various investigative learning practices.

DP7) *Providing flexible tool mediation*: Trialogical learning cannot easily be pursued without appropriate technologies that help the participants to create and share as well as elaborate, reflect and transform knowledge artefacts and practices. Novel collaborative technologies should provide affordances for trialogical learning processes.

These design principles themselves have been evaluated and updated during the project. They must be interpreted and used somewhat differently in different pedagogical contexts (see Ilomäki & Paavola 2008). The challenges and possibilities to develop trialogical practices, for example, at research seminars for educational fields at the universities are somewhat different than in design courses for engineers at the universities of applied sciences, but both can use quite similar technology and benefit from "cross-fertilizing" their ways of working. KP-Lab project's technological design can be examined from the perspective of four *types of mediation* which have been used for specifying the above mentioned design principles to the general aims of the technology development. These types of mediation are reformulations of the ones introduced by Rabardel and Bourmaud (2003), i.e., *epistemic mediation* related to creating and working with knowledge artefacts, *pragmatic mediation* related to organizing and coordinating knowledge-creation processes, *collaborative mediation* concerning building and managing networked communities and social relations required for carrying out knowledge-advancement efforts, and *reflective mediation* in terms of making visible, reflecting on, and transforming knowledge practices. The system is designed, then, to support *multimediation* by providing a shared knowledge space that facilitates all four modes of mediation, and the flexible use of them together.

This paper has, however, concentrated on delineating the theoretical background to the meaning of trialogues, or trialogical learning; pedagogical research and development (see e.g., Muukkonen et al., in press), and technology development with object-bound emphasis (see e.g., Lakkala et al., in press; Paralic & Paralic 2007; Furnadziev et al. 2008) are not the focus in this paper.

Conclusion

The trialogical approach is actually not so much a specific theory as a framework that assists in facilitating sustained collaborative efforts of developing shared objects. In this regard its epistemic status resembles that of the dialogical framework. It is possible to create various kinds of (research) approaches around such a framework. You may always ask to what extent an approach to CSCL, whether it is related to problem-based, project-based or design-based learning, share "trialogical" characteristics and how it could be improved in this regard. The present investigation highlights the importance of complementing the meaning making tradition with a joint construction of shared "trialogical" artefacts and practices. More elaborate models, tools and theories are under (trialogical) construction!

Endnotes

(1) We thank the anonymous reviewer of this paper for pointing out this connection.

(2) The term "trialogues" have been used before in a bit different senses. Dictionaries define trialogues sometimes as a conversation, colloquy or discussion between three people or groups (or see a bit different meaning: Wiley 1994). Etymologically the term might be a bit clumsy in our usage (thanks for Alexander Porshnev for pointing this out) but we are using it to refer to mediated processes (with triadic structures) and as an alternative to dia-logues with the start of 'tria-'. In dialogues interaction happens through words and concepts and by communicating and changing ideas, in trialogues it happens through developing shared "objects" (artefacts, or practices)

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Knowledge and Learning Claims in Blog Conversations: A Discourse Analysis in Social Psychology (DASP) Perspective

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Abstract: This paper explores how discourse analysis in social psychology (DASP) can provide CSCL researchers with insights regarding how students perform knowing and learning. We investigated what counted as knowledge and learning as students in a large undergraduate lecture course shared their understandings of dietary supplements through blog conversations.

Introduction

The purpose of this paper is to illustrate the use of methods from discourse analysis in social psychology (DASP) to understand "how people in groups make sense of situations and of each other" (Suthers, 2006, p. 321). Barriers to engagement in meaningful, "critical" discourse in online environments have been explored in the CSCL literature (Rourke & Kanuka, 2007). While highly structuring discussions is often suggested as a way to promote critical discourse, this strategy can reinforce the idea that the instructor is the sole authority of knowledge, rather than providing space for students to co-construct new knowledge through dialogue. Such co-construction of knowledge is an underlying assumption of several learning theories, highlighting its importance in fostering effective learning environments (e.g. Suthers, 2006). Having knowledge construction as a goal of discussion, yet acting as though there is 'one right way to discuss' or 'one right answer' seem to be contradictory belief systems. Another barrier to learning is the role of prior beliefs. Vosniadou (1994) acknowledged that individuals' epistemological and ontological assumptions often act to limit an individual perspective from undergoing conceptual change. Thus, when students incorporate new information received in educational settings without changing their underlying frameworks, misconceptions can develop. In order to know whether conceptual change has occurred, we must first understand how students are orienting to a learning environment – to the content, to their existing knowledge, and to their beliefs about learning. In an earlier study (Paulus, Payne, & Jahns, in press), we found that student blogging made visible what counted as sources of expert knowledge in the area of nutrition science. In our present study, we delve more deeply into how DASP can provide us with a greater understanding of how students perform knowing and learning in a formal learning environment. We investigated further what counted as knowledge and what counted as learning for participating undergraduate students as they discussed their understandings of nutrition science concepts through blogging. Our research questions were: (1) What counts as valid knowledge claims? and (2) What counts as learning or change?

Context

In this paper, we report findings from a study on a blended learning environment in which undergraduates in a large introductory lecture course in Nutrition (NTR100) engaged in blog conversations as part of their course requirements. NTR100 is required for the B.S. degree in exercise science, nutrition, and nursing and also fulfills an undergraduate general education science requirement. The course is taught in a traditional lecture and discussion section format at a large university in the southeastern region of the United States. The class met twice a week for approximately 50 minutes. Seven graduate teaching assistants (GTAs) were assigned to the course, each being responsible for a 50 minute discussion section per week (approximately 25 students per section). Early in the 2008 spring semester students engaged in blog conversations for two weeks through Blackboard. The 165 students were randomly assigned to one of two blog groups (n=9 to 15) within their discussion sections. The GTAs demonstrated how to use the tool and explained the requirements: (1) to make one post and comment on five posts about their experiences with and understandings of dietary supplements prior to attending the lecture; (2) to make a second post and comment on five additional posts after attending the lecture as to how their understandings of dietary supplements had changed. The GTAs and the course instructor monitored the blog conversations, identifying common student misconceptions, questions, and assumptions. The course instructor then incorporated these common questions and misconceptions into her lecture on the topic of dietary supplements. Seventy-eight percent (78%) of the students fulfilled the posting requirements (ranging from 60-92% of participants making the minimum number of posts and comments), with 66.5 percent of the total participants being female. Posting by GTAs ranged from one to twelve posts across the fourteen blog groups.

Method

DASP assumes that meaning is constructed through language (Potter & Wetherall, 1987; Potter, 1996). In this analytic perspective, it is assumed that discourse constitutes the social world (Phillips & Hardy, 2002), with language seen as possessing a "performative quality" (Wood & Kroger, 2000, p. 5). Through the use of DASP, we can understand how people construct cognitive concepts through language and we used it to understand what our participants' language was doing within a given blog interaction. We approached our analysis with an understanding that "talk creates the social world in a continuous ongoing way," with each participant's discourse standing as only one production among many possibilities (Wood & Kroger, 2000, p. 4). The overarching aim of the analysis process was to identify how the discourse was structured and organized to perform various functions. Our analysis involved "detailed and repeated readings of the discourse against the background of the discourse analytic perspective," with three guiding questions serving to frame our analysis process: (1) Who has authority?; (2) What counts as knowledge?; and (3) How is "learning" constructed? (p. 95). After all of the blog transcripts (247 posts and 1,363 comments) were downloaded for analysis, each researcher read and reread the blog data in its entirety to become familiar with the overall conversation. After several readings of the transcripts, selected portions of the transcripts (based on the guiding questions) were iteratively analyzed. Initial analysis focused on studying the "order/organization/orderliness" of the social interaction of interest (Psathas, 1995, p. 2). We then analyzed each section with the following discourse analytic questions acting to sensitize the process: (1) What is the discourse doing?; (2) How is the discourse constructed to do this?; and (3) What resources are present and being used to perform this activity? (Potter, 2004). Finally, the selected sections were analyzed for what was not present in terms of content and form, as we examined the discourse "creatively in all of its multifarious aspects" in order to "entertain multiple possibilities" (p. 91).

Findings

Our analysis resulted in two discursive constructs: (1) how students constructed valid knowledge claims, and (2) how students constructed learning. We examine both of these constructs in detail below.

Knowledge claims

We noted how students constructed their knowledge of dietary supplements prior to the lecture. Several claims counted as valid sources of knowledge, and students acknowledged sources of authority that acted to validate the knowledge. In many posts, knowledge was constructed by students as being derived from <u>personal experience</u>. We noted that knowledge claims included language constructs such as *It's true because it worked for me, I tried X and Y happened,* as well as *I believe, I think, I heard, I feel* sentence constructions. The source of authority for these knowledge claims was one's personal experience, with students making claims such as "you should listen to your own body" and "if it works for you, you should keep doing it." This post by F005 explicitly identifies personal experience as the primary source of knowledge, claiming that "unless you have had an actual bad experience with them, then it is probably not your place to say they are bad."

> Personally, I do not know a whole lot about supplements, but I do know that if I am not well educated in an area, I am not going to go and nag people who do know a lot about it and tell them how I think it is a bad thing. I think it is ignorant when people complain about something when they do not even know enough about it themselves. So many people say, " I do not take supplements but I think they are bad." Well, unless you have had an actual bad experience with them, then it is probably not your place to say they are bad. Plus, if you take them right and do what it says to do on the bottle then usually they work. For instance, you can not expect a dietary supplement to help you lose weight if you just sit on the couch and hope that it burns all your fat away. Sorry, but it just is not that easy. Does anyone else get annoyed when people act like this? Sorry, not trying to be mean, its just annoying. (F005)

In the absence of personal experience, students deferred to <u>what others in their lives had experienced</u>. Again, some type of experience was the primary authority for the knowledge claims. Language constructions include *I have no experience with supplements, but my mom takes X supplement and has Y outcome.* Students who were more knowledgeable others were given authority by those who did not have direct experience. Mothers, grandparents, friends, coaches, trainers and significant others were referenced as sources of authority for these knowledge claims.

Below is an extended thread of conversation that illustrates what counts as knowledge, and how this is dynamically constructed through the conversation. This post and the comments that follow illustrate how despite some students having no personal experience with a given supplement, "a couple of friends" with experience count as a valid knowledge source.

> I am a [university team] golfer and I used to take protein supplements before coming to college because I wanted to get stronger in order to hit the golf ball farther. I started working with a trainer and he recommended me to drink a protein smoothie every morning. I took it for about 4 months and it really did not make much difference to my body. Then I got told not to use them anymore. . . (F016)

> I haven't taken any protein supplements before, but a couple of my friends have to try and increase their strength. I couldn't really tell a difference in them, but i think that it helped them mentally prepare for their workouts, to run harder or try more reps. (F018)

We identified personal experience as being the primary source of knowledge, with appeals to experts (trainers as doctors) as sources of authority as well. Additionally, many of the commenters relied on the experiences of others (friends) to ground their knowledge claims. At other times, students directly asked their more knowledgeable peers for advice as to what supplements they should be taking. Others responded with constructions such as *I suggest, I recommend, or I would.*

Other knowledge claims were grounded in the <u>authority of "expert" sources</u> such as medical doctor, professor or academic discourse. These claims included constructions such as: *My father is a doctor, and he says X about supplements; I am anemic and my doctor recommends I take Y; I am a nutrition major and X is true about supplements.* The post below explicitly illustrates doctors as a source of authority for this knowledge claim.

> What if a Doctor gives you some sort of supplement to take? Like for instance don't some doctors perscribe (i dont know if that is the right word, it sounds kind of funny, so sorry if its not) :) steriods to help some people get over being sick. You probably won't know a whole lot about that either. I mean, when a doctor gives me medicine that is suppose to make me feel better, i usually just take it and don't ask any questions . . . but I guess my question is do doctor's perscribe supplements that help people and if so, are these good for you or are they harmful? (F074)

Comments which followed reinforced evoking doctors and coaches as sources of authority for knowledge claims.

There were many <u>"common knowledge" claims</u> made in which students constructed knowledge as general statements about society, campus life, and corporate America. Such claims were constructed as: *As a society we want Y; Americans today are X; Students today are Z.* Below participant F058 claims that Americans are lazy and only interested in quick fixes.

> Diet pills seem to be all the craze nowadays. Watch any tv channel and more likely than not, you'll probably see an advertisement for Trimspa or Lipodissolve or some other random "lose-weight-fast" magical diet pill. I think this is the problem with Americans. We don't want to work for anything. We just want results, and we want them fast. (F058)

Learning claims

After students attended the class lecture on dietary supplements, we analyzed their post-lecture blog posts to understand how students constructed what it meant to learn. By far the most prominent way that learning was constructed was as a *change in emotional state*. Constructions such as *I was shocked, I was surprised, I am now curious about, and I am now skeptical* were prevalent, typically around two pieces of new information provided in the lecture: (1) that dietary supplements are not regulated by the government, and (2) that the NCAA closely monitors supplement use of its players. This evoked a knowledge claim that the government is responsible for our health and safety, and the realization that it does not, in fact, play this role in regards to dietary supplements seemed to be quite disturbing to the students. Regarding the NCAA regulations, it was understood that the NCAA has the authority to determine what is acceptable, yet the students resisted that authority on the grounds that their regulations were too strict. In the example below we see an example of this "I was really surprised…It was interesting to see," as well as a request for additional information on the topic.

> I was really surprised about how little the FDA regulated supplements. I was also surprised how much it takes to get a supplement pulled from the market. It seems the government would want to control something that can have major effects on the body. I also think that universities should be more aware of what supplement companies are

> using their studies for since the information can be misleading. It was interesting to see how many supplements are prohibited by the NCAA. I wish Dr. Smith had gone into more detail on how they go about testing for the supplements. Does anybody know any of the methods they use? (F059)

Other students constructed learning as a list of facts from the lecture that they remembered. In the following post learning is constructed with phrases such as “I learned,” “As we learned in lecture,” and “I will be aware.” This participant also noted that some of what was learned was “alarming,” and the commenters use the words “disturbing,” “scary,” “crazy,” and “ridiculous” to describe their responses to what was “learned.” Additionally, in the two final comments made by F055 and F056, we noted again the construction that *everybody knows* in the claims that people should “just work harder” and are “just lazy.”

> I learned several things on Wednesday's lecture. The annual static of 18 billion dollars spent on supplements a year was astonishing to me. I also know of people who seem to take extra supplements in hope for increased results, but as we learned in lecture, there are certain absorption rates for each supplement. Therefore, increased usage at one time is not beneficial. Another alarming fact that we read was the certain affects of certain hormones. The fact that growth hormones can cause internal organs to grow uncontrollably. After class Wednesday, I will also be more aware of the USP labels on supplements (F054)

Intended or actual changes in behavior were articulated as valid ways to construct learning by other students. These changes included the intention to begin or to cease taking supplements, to check with a doctor and/or to do extensive research before taking supplements, and even to check up on what supplements family or friends are currently taking. These constructions included language such as *I will now do X* and *I want to learn more about Y.* What is interesting about the following two posts is that they indicate completely opposite changes in behavior. One indicated that she will keep taking supplements, while the other stated that she will stop taking them.

> As I said in my last blog, I normally take a one a day vitamin for women. I take them on and off. After my last bottle, I kept forgetting to go get more so I didn't take them for about a month. Even now it is hard for me to remember everyday to take them. However, since the lecture on Wednesday I realized I need to keep taking them and take them regularly. (F001)

One of the most intriguing constructions of learning took the form of: I didn’t learn anything…but. After making this claim, the students would go on to write about new understandings they had.

> Well after the lecture on Wednesday I don't feel like I know any more about vitamins and minerals just how to shop for them, what to avoid, and what to look for. I guess I misunderstood what the lecture would be about, I was hoping it would be about the actual supplements, but it was still helpful. I was wondering since there have been so many of us that our parents have told us to take vitamins, is there anyone who's parents or someone close to them that has always told them not to take supplements, and why they shouldn't? (M041)

Finally, some students resisted the information provided by the instructor during the lecture. Information that contradicted previously held beliefs was dealt with by drawing upon personal experience identified as a valid knowledge source. In the below post, participant M023 evokes knowledge claims grounded in personal experience, acting to resist the instructor’s claims regarding a specific supplement.

> During class on Wednesday, Dr. Smith told us that creatine has minimal effects on the body (strength gains, muscle mass, etc). She says that it produces, mostly, psychological effects. Or in other words, a placebo affect. I have been on creatine for about a month and a half and have seen considerable gains, and I know its not just mind over matter. What are y'alls opinions on this subject? (M023)

Particularly interesting about such resistive claims are that they question the very nature of learning, acting to privilege personal experience over “expert” claims presented as part of a formal university course. It is highly unlikely we would observe such resistance in a face-to-face course.

Conclusions

The persistence of blog conversations provides a rich source of data revealing students' assumptions about the subject matter, as well as about what it means to know and to learn. Our findings suggested that personal experiences prevailed as a privileged source of knowledge. We as teachers may see ourselves as authoritative sources of knowledge, but students are not automatically convinced by the knowledge claims that we make. A solid understanding of what expectations learners and instructors are bringing to the learning environment is critical for an effective learning experience. Rourke and Kanuka (2007) argued that dialectical models have been prescribed as most appropriate for educational discussions. However, they also point out that such discussions rarely happen online. Perhaps we can re-orient our focus to understanding how dialogic models may be more appropriate for online conversations, and how findings from DASP analysis of such conversations can inform subsequent face-to-face conversations that target underlying assumptions and student beliefs about knowledge and learning. As CSCL researchers continue to search for ways to investigate intersubjective meaning-making, collaborative knowledge building, and related "cognitive" processes, DASP provides an alternative ontological and epistemological framework that many may find helpful to their work.

Endnotes

(1) All authors contributed equally to this study, with Dr. Paulus as primary author.

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Using Process Mining to Identify Models of Group Decision Making in Chat Data

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Abstract. This paper introduces *process modeling and mining* as an approach to process analysis for CSCL. This approach is particularly relevant for collaborative learning that takes a project-based form, and is applied in this study to online chat data from teams working on a complex task. The groups differed in terms of the number of members and the amount of scaffolding aimed at group processes and task requirements. The models, produced using the HeuristicsMiner algorithm, showed that the group with fewer members that received more instruction in the task requirements had a more linear decision-making process than the group that received instruction in group processes, however neither were an example of a linear, unitary phase model. This approach has relevance both for CSCL research methods and for providing feedback to students on their decision-making processes.

Introduction

While an important feature of research on computer-mediated work and learning is that the researcher has access to detailed traces of the interaction between humans and machines, in an the case of CSCW and CSCL of the interactions between humans mediated by technology, analysing these data from a process perspective is still challenging. With process analysis, we refer to theories and methods that take the temporal nature of problem solving and learning into account. For group work and group learning, it means that the development of groups over time is taken into account. Temporality does not only come into play in quantitative terms (e.g., durations, rates of change), but *order* matters: Since human problem solving and learning is inherently cumulative, the sequence in which experiences are encountered affects how one learns and what one learns (Ritter, Nerb, Lehtinen, & O'Shea, 2007). This can certainly be generalized to groups, and to the communication and interaction processes that take place in groups in addition to learning. Each group has a history, and this history affects their activities and their learning (McGrath & Tschan, 2004).

The order of events has been carefully considered and theorized in conversation analysis (e.g., Schegloff, 2007), that is, for data that takes the form of talk, or talk-like communication such as on-line chat extending typically over seconds or minutes (Stahl, 2006). In studies where interaction and learning is distributed over multiple sessions (and perhaps multiple media, in particular for asynchronous interaction) and where log files are the main data corpora, temporal processes have been less well theorized and process analysis is less often practiced (although there are examples, e.g. Schümmer, Strijbos, & Berkel, 2005). Methodological challenges increase as the time intervals considered for analysis become longer. For instance, as time increases, non-controlled factors will come into play with a higher probability than is the case for short-term collaboration, and changes in group membership become more frequent, thus qualitatively changing the studied 'unit'. Non-linear changes will become more pronounced because of the self-sustaining feedback processes at work in groups over time (Arrow, McGrath, & Behrdal, 2000); that is to say, small differences can have large effects. Development in groups progresses generally in a non-linear fashion, so that both the nature of the data as well as the nature of the underlying processes make it necessary to employ advanced statistical methods (Sloane & Kelly, 2008). Order effects will become more pronounced as groups construct their histories and make use of them, through communication, as resources for interpreting events and planning future actions.

This paper introduces *process modeling and mining* as an approach to process analysis for CSCL. This approach occupies an interesting middle ground between particularistic models of change on one end (formalized as Markov models, for instance) and holistic models of change on the other end (represented as narratives, for instance) of the method spectrum. We begin by characterizing the position of Process Modeling in the overall landscape of process analysis methods and then demonstrate how it can be used to analyze temporal aspects of prototypical CSCL/CSCW data: group decision making that takes place in a chat. The discussion and conclusion describe the models that were produced, and discuss the areas for future research.

Process analysis

Synthesizing earlier reviews on process analysis methods in HCI, CSCW, and CSCL such as Sanderson & Fisher (1994), Olson, Herbsleb & Rueter, (1994) and Ritter & Larkin (1994) and incorporating related work in organizational science (in particular Poole, van de Ven, Dooley, & Holmes, 2000), we distinguish between *atomistic* and *holistic* views of process. The main rationale for this distinction is a view of a process either as being made up of *particulars,* the ordering of which is governed by an underlying law-like process, or a view of process as a whole, a plot-like structure. Along this *granularity* dimension, we can distinguish between (time) series analysis, (event) sequence analysis, and narrative methods.

A second important distinction concerns the *unit of analysis*, which can be variables or events. Variables are attributes of fixed entities defined by measurement (e.g., with a scale) or by a coding and counting procedure. The level of motivation to continue with group work is an example for a variable (typically measured with a Likert scale), the frequency of altruistic behavior displayed in a group is another, typically assessed by *coding and counting*, i.e. content analysis (Strijbos, Martens, Prins, & Jochems, 2006; Wever, Schellens, Valcke, & Keer, 2006). What counts as an event is basically up to the researcher, constrained by theory and informed by research goals; events are not 'raw data', not incidents. Combining these two dimensions of Granularity and Unit of Analysis yields a classification of exemplary process analysis methods as depicted in Table 1 (for more details see Reimann, 2007).

Table 1: Examples for methods classified according to Granularity and Unit of Analysis

Unit of Analysis	**Atomistic**	**← Granularity of process →**	**Holistic**
	Series	**Sequence**	**Narrative**
Variable-oriented	Time series analysis	Quantitative parameters of sequences (e.g. length)	Quantitative parameters of narratives (e.g. word frequencies)
Event-oriented	Stochastic modelling, e.g. Markov models.	Optimal matching methods; Graphical methods; Process-modelling and –mining.	Ethnomethodological approaches; conversation analysis.

Our focus in this paper is on a view of process as a *sequence of events*. The notion of a sequence suggests a more holistic view of process than the notion of a series. For instance, when we speak of a decision making process in a group, we refer to a process that has a beginning and an end, comprises a number of sub-steps (events), and a number of constraints on the order of the sub-steps. However, a sequence does not have to have a plot-like structure, and does not have to convey all the details typical for a narrative. Hence, sequences can be seen as conceptualizations of process more granular than series, and less holistic than narratives. Again, we are not suggesting a strong distinction here, only a heuristically useful one.

Intuitively, for a sequence (and a narrative) the *form* of the sequence matters somehow, while for a series all that matters is preserved in the information contained in immediately adjacent events. Staying with sequences from now on, the question arises how observed sequences can be grouped and classified. One way to do this is to look for *patterns*, for *typical* sequences. One way to find patterns is to use optimal matching algorithms based on a similarity measure for sequences such as the number of changes required to transform one sequence into another (e.g. Abbott & Hrycak, 1990) or to cluster observed sequences in other ways (Kaufman & Rousseeuw, 1990). Another approach for pattern identification is to rely on graphical representations and use visual cues to group sequences into clusters (e.g., Suthers, 2006). Furthermore, representations of processes in a graphical notation format can be quantitatively analyzed, see for instance (Winne & Nesbit, 1995).

A different way to look at sequences is to see them as *generated* by an abstract process - to see observed sequences as *instances* of a *model*. This is in particular appropriate when the sequences in the log files can be expected to reflect structured group activities, such as resulting from scripted collaboration (Weinberger & Fischer, 2006) or from project-based cooperation. In such cases, we can think of groups as *activity systems*—as entities that carry out their projects (Engeström, 1999; McGrath & Tschan, 2004), and of a log file as containing at least in parts records of these structured (planned, coordinated) activities.

In the rest of this paper, we will concentrate on this stance--*seeing observed event sequences as instances of (one or more, but few) process models*--because a good part of CSCL research addresses situations where groups act as activity systems, but where the methodological consequences of this on the analysis of data are as of yet not fully taken into account. We advocate further considering in CSCL research *discreet event model* (DEM) formalisms more intensively, because in this model class synchronicity of events, or parallelism, can be represented and analysed. This is particularly relevant in situations where tasks are accomplished based on a division of labour, as is often the case for project-based teams and with those forms of scripted collaboration that include parallel lines of activities.

Process Modeling as a Method for Sequence Analysis

Process modeling has roots in Business IT and theoretical computer science rather than research computing. A Process Model in the meaning intended here is a formal model, a parsimonious description of all possible activity sequences that are compatible with a model. Processes can be modeled in many forms, e.g. using a system dynamics formalism for continuous process models (Sterman, 2000). The class of process models we want to concentrate on here pertain to the large class of discrete event systems (Cassandras, 1993). Finite state machines are one type of modeling language that can be used to describe and analyze discrete events systems. Another one is the language and theory of Petri nets (Reisig, 1985). Petri nets can be mathematically described as a bipartite directed graph with a finite set of places P, a finite set of transitions T, both represented as nodes (round and rectangular, respectively), and two sets of directed arcs, from places to transitions and from transitions to places, respectively. The Petri net shown in Figure 1, for instance, expresses the fact that all process instances start with A and end in D. It also expresses the fact that the only predecessor to B is A, the B can only be followed by D, and that possible predecessors for D are B, C, and E. Furthermore, it shows that B, C, and E can be executed in parallel, or any order. (Two "technical" transitions are included in the net, and *And Split* (AS) and an *And Join* (AJ) in order to express formally the parallelism between activities B and C).

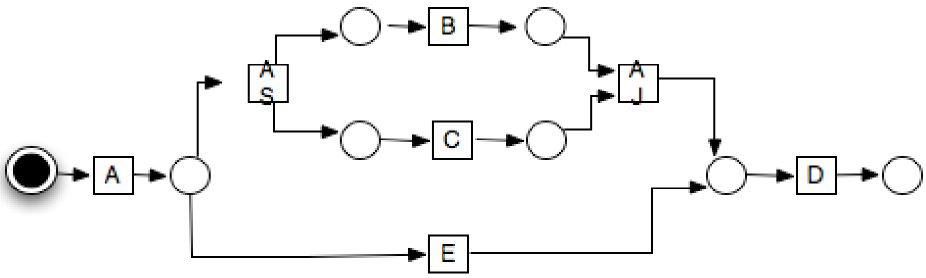


Figure 1: Example for a Petri net description of a process.

A Petri net is not only a graphical representation of a process, but Petri nets can be *executed*. That is to say, one can observe the interactions between the components and study the dynamics of the system modeled. Also, since they have formal semantics, they can be used to determine computationally if a specific activity sequence is commensurate with a model or not; like a grammar, a model can 'parse' an activity sequence. For the same reason, one can use them to simulate potential (non-observed) model behavior computationally, and to compare different models with respect to certain formal parameters. The graphical notation can be exploited for learning purposes; for instance the graphical representations could be made an object for comparison and reflection for the group members, i.e. serve as a mirroring or feedback device (Kay, Yacef, & Reimann, 2007).

In terms of the terminology introduced in this paper, DEMs, e.g., expressed in a Petri net notation, constitute a holistic view of a process: a process has a beginning and an end, it comprises events (activities), and the possible event/activity sequences are subject to more or less numerous constraints. Even a simple Petri net is a basic, but powerful language to represent for instance the logic of a group script. While Petri nets are one out of many possible formalisms to express a process succinctly, they have another advantage: they can be automatically discovered from performance data by process mining, a variant of data mining.

A specific class of data mining methods can be applied in situations where we can expect that a group realizes a multi-step process over time. This would be the case, for instance, when the group behavior is controlled by a script (Dillenbourg & Hong, 2008; Kollar, Fischer, & Hesse, 2006), or when the nature of the task suggests a specific sequence of activities, such as phases of a decision making process (Poole & Roth, 1989b). Process model mining (or process mining, for short) assumes that (a subset of) observed activities can be related to one or more processes, or in other words that (a subset of) observed activities constitutes an instance of a process. We look next at such a case: a normative model of group decision making is seen as constituting a process, the enacted decision sequences as instances thereof.

The Temporal Nature of Decision Making in Groups

Decision making is an important element of all forms or team work where the task is not completely routine. It is also an element of groups that have learning as their main purpose, to the extent that their interaction and communication is not completely prescribed. One of the first publications regarding group decision making appeared in the 1950s, when Bales and Strodtbeck (1951) developed a method for coding interaction that occurred in small group meetings. They hypothesized that members of problem solving groups tend to go through several distinct phases, emphasizing problems of *orientation* at first (e.g. giving or asking for information and clarifications), then problems of *evaluation* (e.g. giving or asking for opinions and evaluations) and finally problems of *control* (e.g. suggesting or asking for directions or ways of action).

In the 1980s, (Poole & Roth, 1989b) challenged the unitary phase models that Bales and Strodtbeck introduced in 1951. They argued that decision behaviour in groups does not follow a linear set of phases in order to reach a decision, but is a much more complex process instead. They proposed a contingency model, stating that multiple variables like task nature or group composition cause differences in the group's developmental path. 'Rather than picturing group decision making as a series of phasic "blocks" dropped one after another into sequence, the model describes development as a series of intertwining threads of activity that evolve simultaneously and interlock in different patterns over time' (p. 328).

To answer the question of *how* these variables cause variations in decision making patterns, it was essential for Poole and Roth to build a typology of the existing decision paths. In order to do that, they studied 47 decisions made by 29 groups. Their research procedure consisted of four steps. First, they coded decision making interaction with the Decision Function Coding Scheme (DFCS), which categorizes statements based on their function in the group. Basic categories of functions are: problem analysis, group orientation, and solution activities. Second, they grouped coherent statements together and identified decision phases. Third, to get an overview, they plotted this sequence of phases on a timeline. Fourth, they applied statistical methods to group these timelines and thus developed a typology of different patterns.

Their results showed that 11 out of the 47 decisions had a unitary sequence of activities, 22 had a complex cyclic structure in which groups cycled through problem-solution sequences multiple times, and the remaining 14 decisions followed a solution-oriented path, in which solution development dominated over problem statements and group orientation. This indicates that group decision making is indeed more complex than the unitary phase models assumed. In follow-up research, Poole and Roth tested the contingency model to find out which variables predicted the group's decision path (Poole & Roth, 1989a). They examined how differences in three groups of independent variables, being objective task characteristics (e.g. openness, goal clarity), group task characteristics (e.g. novelty, innovativeness), and group structural characteristics (e.g. cohesiveness, size), affected the decision making process. The analysis showed that group structure and task characteristics were the most powerful predictors of the unitariness and solution orientation of a group's decision path.

Since its emergence in the 1980s, the overall goal of functional research has been to gain understanding of how these communication functions relate to the *effectiveness* of the group decision (Gouran, 1999; Poole, 1999). One of the most sophisticated functional theories is Gouran & Hirokawa's Functional Theory of Group Decision Making, which holds that communication has to fulfil several distinct task requirements in order to result in effective decision making (Gouran & Hirokawa, 1996). More specifically, effective decision making depends on five factors: 1) the group's understanding of the issue at hand, including the nature and possible causes of the problem, 2) the group's understanding of the criteria for an acceptable solution alternative, 3) generation of as many realistic and applicable solution alternatives as possible, 4) evaluation of the positive properties or consequences of the generated alternatives, and 5) evaluation of the negative properties or consequences of the generated alternatives. Groups that communicate in a way that fulfils all these requirements will make better decisions than groups that do not.

Over the past two decades, research on Gouran & Hirokawa's Functional Theory has build up a solid base of evidence and was expanded to incorporate environmental factors (cognitive, affiliative and egocentric constraints) that affect *how well* communication fulfils the task requirements (Gouran & Hirokawa, 1996; Wittenbaum et al., 2004). However, more detailed research into the relation between specific communication functions and group performance was inconclusive. In earlier work, researchers found a correlation between the evaluation of *positive* aspects of solution alternatives and the group's performance (Graham, Papa, & McPherson, 1997; Propp & Nelson, 1996), but in a more recent meta-analysis, Orlitzky and Hirokawa (2001) found that the assessment of *negative* consequences of alternatives had the strongest correlation to group effectiveness. According to them, the nature of the task most likely dictates whether it is more important to assess positive or negative aspects of solutions (Orlitzky & Hirokawa, 2001).

On the other hand, problem analysis and development of solution criteria are two communication functions that were found to affect decision performance in almost all cases (Graham et al., 1997; Hirokawa & Salazar, 1999). Interestingly, the generation of alternatives seems to be largely *unrelated* to decision making performance. Brainstorming and idea-generation are often highly valued, but these results indicate that no clear relationship exists between the amount of ideas and the quality of the solution. One explanation for this observation is that groups that spend a lot of time on idea-generation have less time left to perform functions that are more important to decision quality (Orlitzky & Hirokawa, 2001).

This Study

Our research question pertains to the development of group decisions over time. We specifically build on former work (Poole & Roth, 1989a, 1989b) that introduces the notion that group decision making neither follows a unitary sequence (e.g. orientation – evaluation – control) nor is it completely contingent on characteristics of the situation, but that groups actively structure their decisions. In this conceptualisation, normative decision models play the role or a resource that groups can and will access and employ, but that do not completely account for groups' behaviour. Poole's model assumes further that groups work on multiple "threads" at the same time, and decisions with respect to all threads are mingled together in observable behaviour. These threads are: task process behaviour (e.g. orientation, evaluation), relationship management (e.g., conflict, integration), and topical focus (substantive issues involved in the task).

Setup

Data were obtained using a tool called Snooker (Ullman, Peters, & Reimann, 2005) from a group of graduate students who worked on a complex problem involving a system dynamics task without meeting face to face over a number of sessions (Reimann, Thompson, & Weinel, 2007). Weekly chat meetings were conducted including all students and a session moderator, but participants were free to meet in the chat at other times. Students were given instructions regarding management of their teams. Part of this was that the lecturer and tutor would not be micro-managing the team. Instead, students would be expected to coordinate their own work within their team. This required frequent decision making regarding not only aspects of the task (e.g. which elements to include in the solution) but also regarding aspects of group work such as distribution of tasks and coordination of on-line meetings.

The participants in this study were two groups of postgraduate students who enrolled for an on-line course on system dynamics. Group A consisted of three female students and one male student. These students were scaffolded in managing their group processes, however received little scaffolding on the requirements of the task. Group B consisted of fewer students, three female in total, however one student missed a large component of the course, and so only two of the group members participated in the first three chat sessions only involved two of the three group members. Group B received much more guidance than Group A in the requirements of the task. They did have some experience in managing the group processes using the available tools (both the wiki and Snooker), however it was less extensive than that experienced by students in Group A.

The learning environment combined synchronous and asynchronous communication components. The main asynchronous collaboration medium used in this course was a wiki engine, not further discussed here. Weekly chat meetings were conducted including all students and a session moderator (one of the lecturers). The chat environment Snooker was accessible through any web browser, and combines a chat area, a notes area, and a shared whiteboard.

Coding

To be able to reliably describe processes, content analysis of communication transcripts should involve segmenting the data stream into meaningful units, and coding these units with a theoretical coding scheme (Poole, Ven, Dooley, & Holmes, 2000). Each chat statement was considered one meaningful unit. Minor unitizing adjustments were made to the dataset to simplify the coding process. For example, spelling or typing corrections and statements that consisted of a single question mark were excluded. In addition, when a statement consisted of more than one sentence and both sentences could be assigned a different code, the statement was be split, and the second sentence was set to follow the first with a one-second delay. These modifications were infrequent, however, and for the most part statements were left untouched. Since there were very few changes made to the segments, there was no need for a segmentation reliability measure (Strijbos, Martens, Prins, & Jochems, 2006). The Decision Function Coding Scheme (DFCS, Poole & Holmes, 1995; Poole & Roth, 1989a) was used to code each of these statements in the chat log. The DFCS is a well-established coding scheme, used to categorize statements according to the function that they serve in group communication. It makes use of six categories: 1) problem definition, 2) orientation, 3) solution development, 4) non-task, 5) simple agreement, and 6) simple disagreement. Table 1 shows an overview these categories. Small modifications were made to the original coding scheme by Poole and Holmes (1995): The categories were simplified and phasic markers were omitted to better suit the scheme to the current research questions.

Problem definition statements are statements that relate to the group's understanding of the problem or decision making task at hand. For example: "We need to decide if we should use a more recent timeframe". Orientation statements are statements that relate to the group process. These statements are attempts to orient the group, providing information and steering the group in a direction, or reflecting on the group process: "Why don't we do what we suggested from the start?" or "Anyone got any suggestions?". Solution development statements are all statements that are related to solutions. Statements could set criteria for solutions, suggest alternatives, elaborate on an alternative, evaluate an alternative, or confirm the solution (e.g. "Can I just confirm that we have all agreed to go with Charles' proposal?"). The non-task statements are statements that are not aimed toward making a decision or solving the problem. These include greetings, the making of appointments and other coordination statements. Finally, the simple agreement/disagreement statements are all statements that consist of a simple "Yes" or "No", or indicate agreement or disagreement in any other way. This coding scheme was applied to utterances that were classified as being part of a larger decision making process, of which 35 instances were identified in the chat log of the two groups.

A first coder analysed the complete chat log for both groups. The second coder coded 9 of the 35 decision instances (25%) and agreement on these instances yielded a Cohen's Kappa of .65. After a final discussion session, differences were reviewed and codes were changed, which resulted in a final agreement of .98.

Table 2: The Decision Function Coding Scheme

1	Problem definition: Statements that define or state the causes behind a problem, or evaluate problem analysis statements
2	Orientation: Statements that attempt to orient or guide the group's processes, including simple repetitions of others' statements or reflections on the group process
3	Solution development
	3a. Solution analysis: Statements that concern new 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. They are neutral in character and provide ideas or information about alternatives
	3d. Solution evaluation: Statements that evaluate alternatives and give reasons, implicit or explicit, for these evaluations (+ for positive, - for negative valence)
	3e. Solution confirmation: Statements that state the decision in its final form or ask the group for a final confirmation.
4	Non-task: Statements that do not have anything to do with the decision task
5	Simple agreement
6	Simple disagreement

Process Mining Algorithm and Tool

Given the expectation that the decision development would not be a simple unitary sequence, and that the chat data would contain "noise" from a theoretical point of view even after data cleaning, a non-deterministic method for process modelling was needed. While the above Petri Net model class has many advantages, this model class is not easily fitted to data that contain noise (i.e., not all events can be seen as belonging to the model) and/or are incomplete (not all model elements of the model are observed at least one time). What is needed for noisy and/or incomplete data is a model type that makes less strong assumptions on the relation between events observed and relations in the model. One such model class are *dependency graphs*, along with a *HeuristicsmMiner algorithm* to discover models from event logs (Weijters, Aalst, & Medeiros, 2006).

The HeuristicsMiner uses a frequency based metric to express the degree of certainty of a dependency relation between two events *A* and *B* based on an event log *W*, expressed as: $A =>_w B$. With $|a >_w b|$ standing for the *number* of times *a* is followed by *b* ($a >_w b$), the metric is calculated as:

$$A \Rightarrow_W B = \left(\frac{|a >_W b| - |b >_W a|}{|a >_W b| + |b >_W a| + 1}\right)$$

In words: The number of times a is followed by b is subtracted from number of times a follows b and this difference is divided by the sum of these two relations, plus 1. This metric takes values between 1.0 and -1.0, with a value close to 1.0 indicating a high certainty that b follows a, and values close to -1.0 an almost definite certainty of the reverse (a follows b). The metric's value is dependent on the number of cases. For instance, if b follows a 5 out of 6 times, and the other order never occurs, then a =>w b = 5/6 = 0.833. If a follows a 50 times and the other order never occurs, then the value is 50/51 = .980. Instead of using a fixed value for $a =>_w b$ as the threshold, the heuristic to take the highest score to decide which relation to put into the dependency graph is appropriate if we request that all observed activities should be connected. The HeuristicsMiner algorithm can not only deal with noisy and incomplete event logs, but also with short loops (e.g. ACCB, ACCCB) and with non-free-choice situations: in some process models the choice between two activities depends on choices made in other parts of the process model.

To perform the process mining procedure, the coded transcript needed to be imported into the ProM tool (Aalst van der et al., 2007). Since event logs exist in many different file formats, the ProM tool works with one generic XML format, Mining−XML or MXML for short. For the current study, a special plug−in was developed to convert the Snooker chat transcript, which was stored in a Microsoft Excel file, into MXML format. This MXML file was then imported into ProM and the data was analyzed. Before running the analysis, a filter was set up to discard any events of the non−task statement category. Even though unrelated chat statements occur regularly, it is improbable that they make up a specific phase in the decision process, and are therefore discarded from the model generating process.

Results

In Group A, the final event log consisted of 1115 events. These 1115 events were spread out over 23 decision instances. The mean number of events per instance was 48, with a minimum of six events per instance and a maximum of 234 events per instance. To clarify, this means that the group reached their final decision in six statements in one case, but the longest decision took 234 statements. On average, to come to a decision took 48 contributions. Group B produced a final transcript of 324 events, spread out over 12 decision instances. The average number of statements that were necessary to reach a solution was 27, with a minimum of five and a maximum of 59. Table 3 shows the numbers and frequencies of all the decision functions. In both groups, the majority of statements related to orientation of the group, indicating an important role for monitoring and guiding group processes. Concerning the solution related statements; the generation of solution alternatives appears to be the most frequent activity, followed by solution elaboration. Confirming solutions and generating criteria for solutions were performed less frequently, and evaluating solutions was the least frequent activity. Interestingly, negative responses as indicated by disagreement and negative evaluations were very rare, making up just about one per cent of all their disagreement. Another interesting finding is the low frequency of problem definition statements. Only in 5.3% of all the statements did the students refer to the actual problem or decision at hand. Finally, there is a considerable amount of non−task communication, indicating that there were off−topic conversations even when the group was engaged in a decision case.

Table 3: Frequencies of decision functions

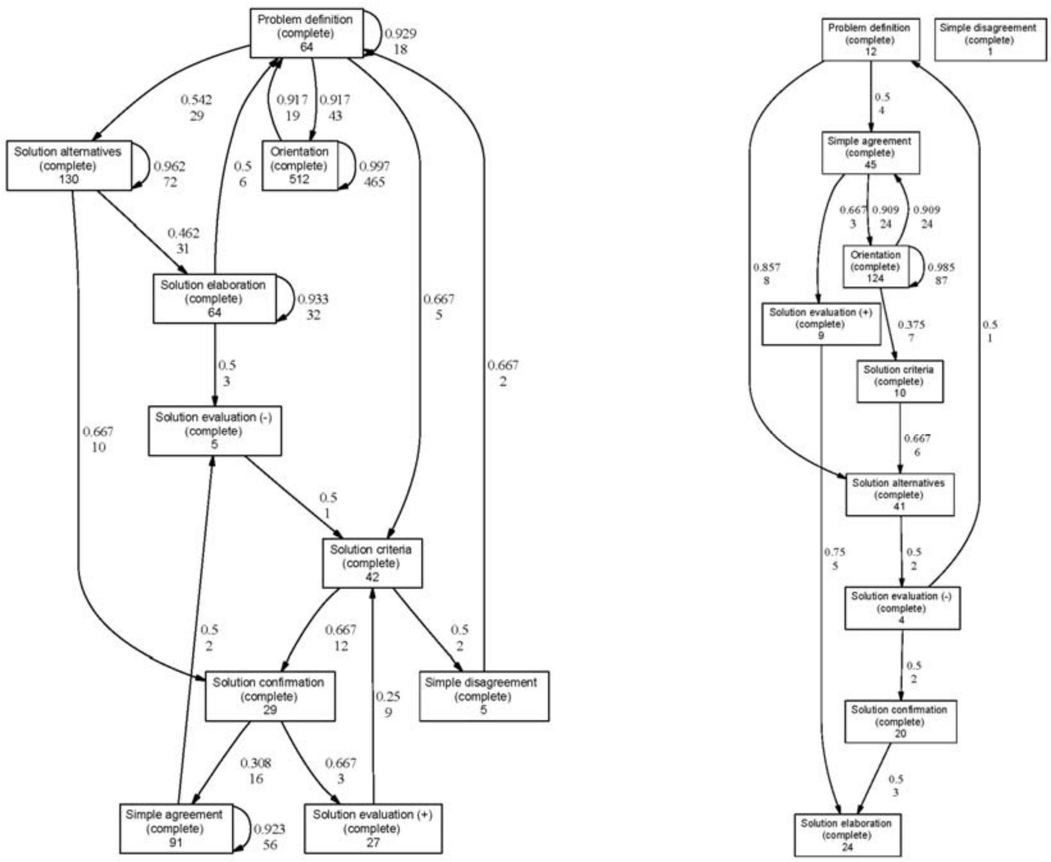
	Group A		Group B		Total	
Function	*N*	Frequency	*N*	Frequency	*N*	Frequency
Problem definition	64	5.7%	12	3.7%	76	5.3%
Orientation	512	45.9%	124	38.3%	636	44.2%
Solution criteria	42	3.8%	10	3.1%	52	3.6%
Solution alternatives	130	11.7%	41	12.7%	171	11.9%
Solution elaboration	64	5.7%	24	7.4%	88	6.1%
Solution evaluation (positive)	27	2.4%	9	2.8%	36	2.5%
Solution evaluation (negative)	5	0.4%	4	1.2%	9	0.6%
Solution confirmation	29	2.6%	20	6.2%	49	3.4%
Non-task	146	13.1%	34	10.5%	180	12.5%
Simple agreement	91	8.2%	45	13.9%	136	9.5%
Simple disagreement	5	0.4%	1	0.3%	6	0.4%

Note: frequencies are rounded to one decimal, causing minor rounding errors.

In a second step, we examined the *development* of decisions, using proces mining techniques. The HeuristicsMiner's threshold parameters were kept at their default values of 0.9 (dependency threshold), 10 (positive observations threshold), and 0.05 (relative−to−best threshold). These thresholds indicate which event dependencies are added to the model in addition to the best dependencies. First, all dependencies with a value higher than the dependency threshold are added. Second, regardless of the dependency value, each relation that occurs at least as many times as the positive observation threshold is included. Finally, each dependency that differs less from the best dependency than the relative-to-best-threshold value is added as well.

The resulting dependency graphs are displayed in Figure 2 (A and B). The arcs on the right side of the boxes that point back at their own box indicate loops, meaning that statements of this type often occurred multiple times in a row. The numbers along the arcs show the dependency of the relationship between two events, as explained previously. The second number indicates the number of times this order of events occurred. The numbers in the boxes indicate the frequency of this event.

*The Group A decision model***.** Beginning with a period of problem definition, the model in Figure 2A shows that outgoing arcs flow to discussion of solution alternatives, group orientation, and discussion of solution criteria. The dependencies scores indicate that problem definition statements are most often followed by extensive periods of group orientation. Note the high degree of cycling and the high dependencies. The group then shifts to discussion of either solution criteria or solution alternatives. In most cases, after solution alternatives are generated, the group proceeds to decision confirmation, but in some cases, generation of alternatives is followed by elaboration and evaluation. After deciding on solution criteria, the most common next event is solution confirmation. Note that in some paths, generation of alternatives does not occur. Interestingly, if there was disagreement after deciding on criteria, the group often started from the top again. The confirmation of solutions was followed by positive evaluation or agreement. In some cases the positive evaluation statements triggered discussion of the criteria again. Incidentally, after agreeing upon a confirmed solution, negative aspects of the solution were found and the group cycled back to the generation of solution criteria.



A B

Figure 2: Process models in form of transition diagrams for teams A and B

The Group B decision model. The model displayed in Figure 2B at first sight looks very linear. Also of interest is that there is an unconnected box in the model. Simple disagreement only occurred once in the complete transcript, and the miner was therefore not able to discover any relation with other events. After the problem definition, the group took one of two paths: they either moved through a phase of agreement and orientation to the generation of criteria, followed by generation alternatives, or they started generating solution alternatives directly. The latter path was more common. The solutions were then evaluated, and a final solution was confirmed. In addition, the model shows a phase of elaboration as final event in the process. There is one peculiar sequence of events where the group moves to positive evaluation of alternatives right after they agreed upon a problem definition. They then move directly to the final phase, which is solution elaboration. One possible reason for this is that the group used asynchronous communication means in the form of a wiki-platform in parallel with the Snooker tool. We observed that some of the decision events took place on the wiki platform, making them unavailable to the miner. These kinds of missing data in the event log can cause such odd sequences in the resulting model.

Conclusions

The models shown in Figure 2 do not resemble a linear, unitary phase model. They are, in accordance with previous findings (Poole & Holmes, 1995), unstructured, complex, and cyclic. The decision process takes a different path each time it is executed; looping and cycling back to previous events also occurred often. Nevertheless, the graphic representation of the models makes the differences and similarities between the groups clearly visible.

We have argued that creating *models* from interaction data has various advantages, both as a research method as well as a means to provide feedback to teams. In this paper, we had only space to illustrate their value as a process analysis method for cases where groups can be conceptualized as activity systems. In this situation, it is appropriate to see the event sequences produced by groups as at least partially generated by rules that govern groups' (accountable) work, and to formalize these rules (pertaining to division of labour, decision making etc.) as a process model. The task for the researcher is then to identify the process model that accounts most parsimoniously for the observed process instances and/or to compare the fit of the observed process enactments with the stipulated group process. We see it as an advantage of this approach that it allows for a clean separation between observed event sequences and a model that represents these sequences in a generalized manner. For other forms of sequence analysis, such as pattern analysis, it is more complex to decide what is an instance, and what a generalization of a set of instances. Another advantage is that specific model classes, such as the discreet event models used here, have well-understood notions of concurrency, of parallelism.

However, models are always wrong, unless they identical with the 'original'. Models are wrong because they reduce the information contained in the data modelled. Therefore, process mining using heuristics is subject to all that can go wrong with data mining (Han & Kamber, 2001) and inductive approaches in general. This means that the quality of a model depends on the quality and representativeness of the data on which it has been constructed. In addition to this general concern, process models may overfit or underfit the data. We will work with the strategy suggested by (Aalst van der et al., 2008) to reduce overfitting by "folding" regions in transition nets as displayed in Figure 2 into Petri nets. Also, we are beginning to analyze the effects of displaying process diagrams back to groups of students as a form of feedback. Research such as this will yield further insights into the value of process models both as a research tool as well as a resource for groups.

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Recognizing Creative Thinking in Graphical e-Discussions Using Artificial Intelligence Graph-Matching Techniques

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Abstract: Many approaches to analyzing online argumentation focus on explicit reasoning and overlook the creative emergence of new ideas. The value of a dialogic analytic framework including creative emergence was tested through applying it to the coding and analysis of undergraduate synchronous e-discussions using a graphical interface within the EU funded project ARGUNAUT. Qualitative analysis found that critical reasoning functioned to 'deepen' the graph through unpacking assumptions whilst creative emergence of new perspectives produced 'widening' moves. This distinction between deepening and widening was successfully used as the basis for an artificial intelligence (AI) graph-matching algorithm. Given examples of deepening and widening from real e-discussions, the AI algorithm was able to successfully find other occurrences of such moves within new e-discussions. This supports our claim to distinguish between these two aspects of shared thinking and has the potential to provide awareness indicators as a support for e-moderation.

Introduction

This paper reports on part of a European research project, called ARGUNAUT (De Groot, Drachman, Hever, Schwarz, Hoppe, Harrer, De Laat, Wegerif, McLaren, & Baurens, 2007; Hever, De Groot, De Laat, Harrer, Hoppe, McLaren, & Scheuer, 2007; http://www.argunaut.org/), presenting some findings regarding coding for creative thinking in a way that feeds into online awareness tools supporting the moderation of online discussions. The ARGUNAUT system that has been developed during the project uses the graphical e-discussion environments Digalo (dito.ais.fraunhofer.de/digalo/) and FreeStyler (www.collide.info/software) for students, along with a Moderators Interface (MI) for teachers, which includes a range of awareness indicators and tools for intervention designed to provide summarised information and make the task of moderation easier.

As well as providing awareness of relative participation, types of messages, and the relationships between people through social network diagrams, we also sought to provide awareness indicators for the quality of discussions. It is in this context that we used discourse analysis to explore effective reasoning and collaboration. In this paper we focus on research into the evocation and coding of creative thinking in contrast to both critical and dialectical reasoning. We report how this distinction was used by artificial intelligence (AI) graph-matching techniques to identify creative thinking (as well as critical reasoning) in new discussions.

The Dialogic Challenge for Coding

Most schemes applied to analyze online argumentation (e.g. those developed originally by Toulmin, Van Eemeren and Walton, see Andreissen, 2006 for discussion) focus on explicit reasoning in the form of claims, challenges to claims and reasons in support of claims. This approach is good at picking up critical reasoning but ignores more creative forms of shared thinking. As opposed to 'dialectics', which always begins as a theory of argument, Bakhtin's 'dialogic' approach begins with 'living' dialogue (Bakhtin, 1986). For Bakhtin consensus or unanimity or intersubjectivity is not the aim of dialogue; rather, the aim is a deepening and expanding of awareness that Bakhtin refers to as inter-illumination. In dialogues voices interact in unpredictable ways to produce new voices and new perspectives that enable participants to see the topic of the dialogue in a new way (Wegerif, 2007).

On the ARGUNAUT project we expanded the dimensions of coding from the traditional single dimension of critical thinking with its focus on claims, counterclaims and reasons (D1) to include the dimension of creative reasoning understood as a sort of dance of perspectives (D2) in which each new perspective or point of view on a problem is labelled and also the dimension of dialogic engagement which includes not only 'addressivity' (language explicitly addressing the other such as pronouns) and expressions of empathy but also expressions of doubt, changes of mind, 'ventriloquation' (a term from Bakhtin for the presence of another voice within an utterance) and elicitation of the views of others (D3) and finally moderating moves (D4).

To help us code the complex online e-discussions produced in the course of the ARGUNAUT project we developed sequence diagrams, which are visual representations showing both the number and length of sequences of messages and the branching of sequences at different points during the discussion. These sequence diagrams give a visual reference to widening.

This coding scheme and approach to analysis has been tested and further developed through the analysis of over sixty free-form e-discussions created by approximately 100 undergraduates and 12 post-graduate students in the UK. These so-called "discussion maps" were coded with identifying key events such as 'creative widening,' which occurred over several messages. The codes were then used to develop classifiers using artificial intelligence techniques (McLaren, Scheuer, De Laat, Hever, De Groot & Rosé, 2007; Scheuer & McLaren, 2008; Mikšátko & McLaren, 2008) that are able to detect and classify the events automatically and inform the moderator. This is done by a component of the ARGUNAUT system called the "Deep Loop," described below.

An Illustration of Coding for Widening

We began with a very complex Digalo map produced by a group of five undergraduates in response to the question: 'Will the Internet bring the world together or deepen its divisions?' To help the analysis we reorganized the map to a sequence diagram that enabled us to see the critical branching moments more clearly (see Figure 1).

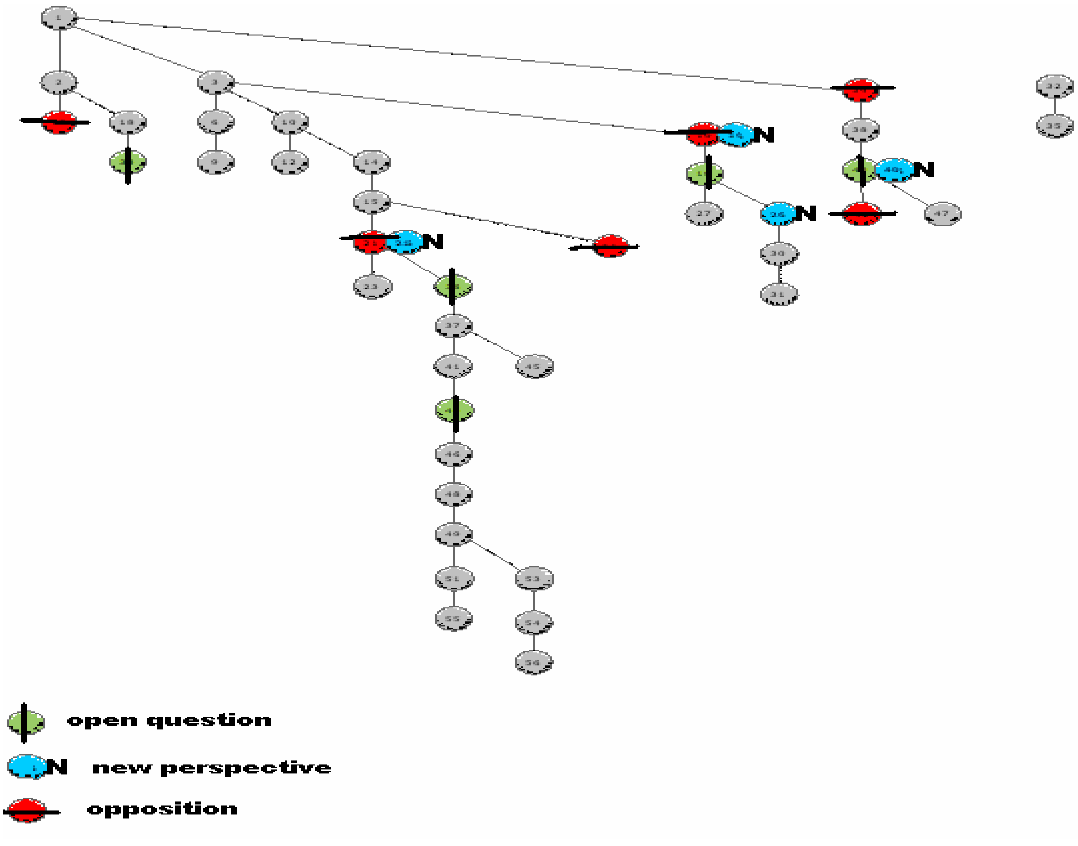

Figure 1 Sequence diagram of a Digalo map

This e-discussion map showed us the key moments when new perspectives emerged (the dots with an 'N' next to them) and these coincided with branching moves in the sequence diagram and seemed typically to occur shortly after oppositions (dots with horizontal line) and open questions (dots with vertical line). Focusing on each key incident we were able to pursue qualitative interpretation of the factors leading to the emergence of new perspectives, and we followed these up with Critical Event Recall interviews with the participants. Figure 2 below illustrates a specific example of the emergence of new meaning. In this snippet of e-discussion, the discussants exchange ideas about awareness of other cultures, ethics, and religions. The "new perspective" emerges when one student suggests that we may "create a divide" by becoming aware of different cultures, ethics, and religions. In the context this is a new and unexpected perspective.

Once we had used this method to code the maps with a breakdown into clusters indicating widening and deepening, i.e., sets of graph nodes indicating the cluster, such as 15, 21, 23, and 36 in Figure 2, this was subjected to computational analysis to see if artificial intelligence techniques could match the patterns and discover new incidents of creativity in new maps.

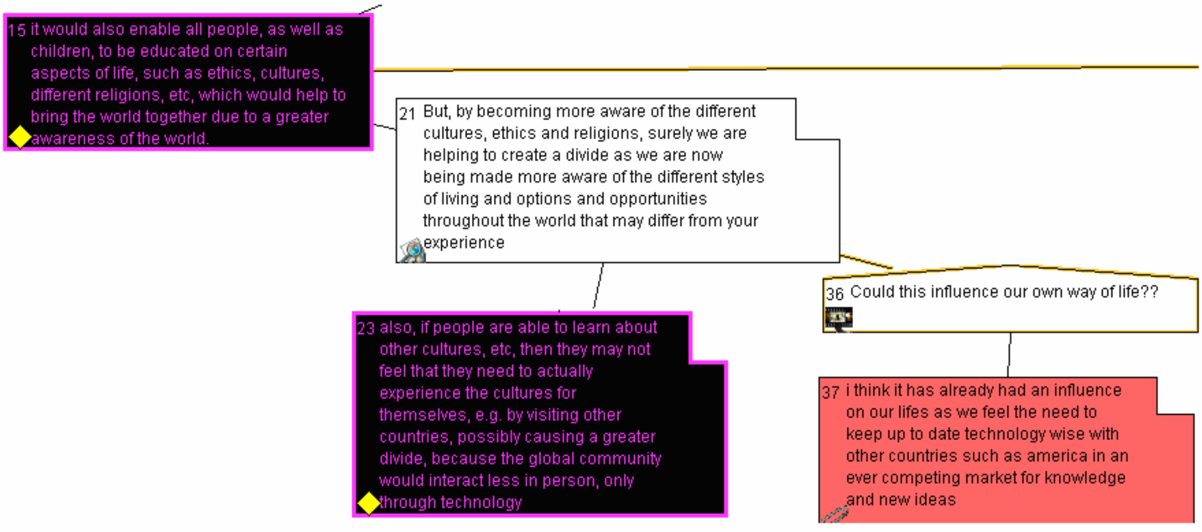

Figure 2. A cluster of shapes around the emergence of a new perspective

A Computational Model to Explore Deepening and Widening

As part of what we call the "Deep Loop" of the ARGUNAUT system, we have developed a computational model called ***DOCE*** (***D****etection* ***o****f* ***C****lusters by* ***E****xample*) (Mikšátko & McLaren, 2008) that allows us to identify places in e-discussions in which students may be deepening or widening the conversation, as well as other types of complex conversational moves. DOCE is one of a number of tools that we developed to assist a teacher in monitoring the on-going simultaneous e-discussions of several groups of collaborating students. The students use the collaborative software tools Digalo or FreeStyler to communicate with one another, with each student working on his or her own computer, while a tool called the "Moderator's Interface" provides the teacher with a variety of important views of the on-going discussions. One of the "views" provided to the teachers is a set of *alerts* that point to critical aspects of the conversation, such as whether students are staying on topic and supporting their claims with good justifications. Some alerts are supported by relatively simple calculations (e.g., how often each student has contributed to the conversation, whether students use swear words), some by machine-learned classifiers (McLaren *et al*, 2007; Scheuer & McLaren, 2008), and some by the DOCE algorithm (Mikšátko & McLaren, 2008).

In particular, the DOCE algorithm identifies *clusters* of contributions, for example, several contributions made by different students that indicate deepening or widening of a conversation. DOCE is based on the idea of using cluster *examples* to find similar clusters in new discussions, inspired by the subfield of artificial intelligence known as case-based reasoning (Kolodner, 1993; McLaren, 2003). DOCE operates by a researcher or teacher selecting a cluster in an existing e-discussion that exemplifies an interesting pattern (e.g. connected individual contributions that provide a good example of deepening). The example cluster (also called a "model graph" in the following text) is then used as a search query for similar clusters across other discussion maps (called "input graphs"). The algorithm uses both structural features (e.g., the pre-specified types of contributions made by students – for instance, "claim" or "question" – and types of links between contributions – for instance, "supporting" or "opposing") and textual features (i.e., the text provided by the students, unigrams, bigrams, and syntactic structures from that text) of the discussion map to find similar clusters. The output of the algorithm is a list of matching clusters in the discussion map(s), sorted according to a similarity rating, as is done by web search engines, such as Google. DOCE can be used as a tool to help researchers find and analyze clusters, such as examples of deepening or widening or it can be used as a "live" classifier of clusters – characteristic example(s) representing a cluster of a particular type are stored in the database and used later as queries for automated cluster detection. Details about the underlying DOCE algorithm are provided in (Mikšátko & McLaren, 2008).

An Experiment to Test the Effectiveness of the Computational Model

We took hand-annotated examples of deepening and widening (annotated by the members of the Exeter team on the co-author list) from actual classroom discussion maps, and tested whether DOCE was able to use those examples to find the *other* examples of deepening and widening in our data set. More specifically, we took 30 annotated examples of both deepening and widening from 14 distinct discussion maps, and did the following:

For each annotated example, we ran DOCE with that annotation as the model graph against all of the other 13 discussion maps (i.e., as “input graphs”, as discussed above):

- We considered a *relevant match* to be 70% overlap, e.g., the following model graph and found cluster in an input graph would constitute a relevant match, since there is a 75% node overlap (bold-faced nodes overlap): Model Graph (Node1, *Node3, Node4, Node5*); Cluster in Input Graph (*Node3, Node4, Node5*, Node6)
- We varied parameters, such as the number (N) of clusters that were returned by DOCE and the relative impact of structural and textual properties on the similarity score of cluster pairs (e.g., Is it more important that texts or shape types are similar?).
- We evaluated recall, precision, and recall+precision on each run of DOCE. These are metrics typically used in information retrieval and were calculated as follows: *Recall* represents the number of relevant matches in the Top N divided by the count of annotations in the searched map (value between 0 and 1.0) whereas *Precision* is the number of relevant matches in the Top N divided by N (value between 0 and 1.0).

Results on the Effectiveness of the Computational Model

The results of our experiment are summarized in figures 3 and 4. Note, first of all, that the *best* results for deepening and widening are quite reasonable (the middle bar for recall, precision, and recall+precision in each of the figures), especially for recall, the metric we consider most important. By “best” result, we mean the human-annotated cluster that led to the best recall and precision values when used as a model graph to DOCE. For instance, notice that the best deepening model graph (the middle bar in each of the first two sets of three metrics in Figure 3) led to a recall of 0.80 and precision of 0.52. The *average* results, calculated across *all* of the annotated clusters (the leftmost bar for recall, precision, and recall+precision in each of the figures), are not good (e.g., the 0.42 recall and 0.27 precision in Figure 3 are very poor). However, focusing on the best results is more important because, by the nature of the DOCE algorithm, only the *best* examples of deepening and widening will subsequently be used as model graphs to DOCE. That is, once one finds the best model for a particular cluster type – or the best set of models – that model (or models) will then be used as a “search probe” for all subsequent searches.

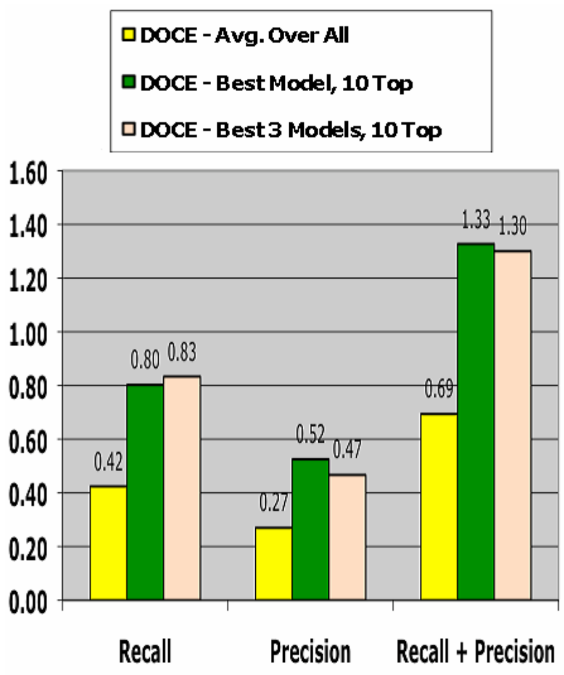

Figure 3. Results of DOCE on the deepening clusters

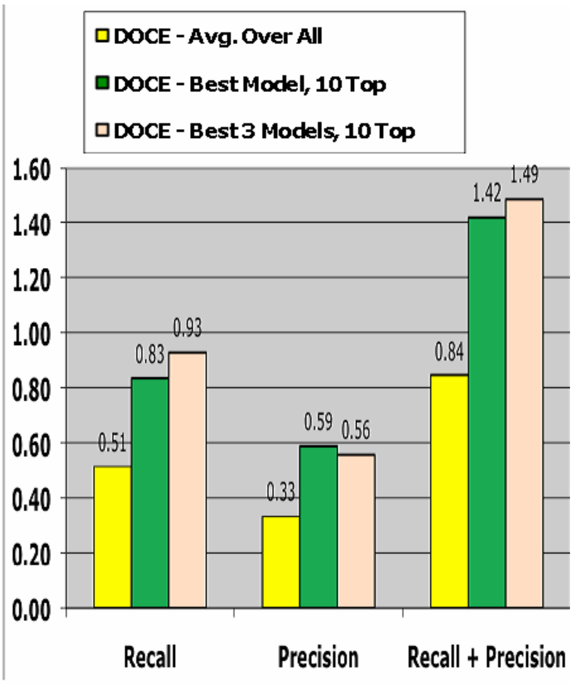

Figure 4. Results of DOCE on widening clusters

We also tested whether *combining* the results of multiple runs of DOCE might further improve the results. That is, we wanted to answer the question: Can multiple, high-quality clusters lead to even better results than single "best" clusters in retrieving relevant clusters? We implemented this combination by ranking the results according to the average relevance scores of the three single-best models. The third bar in each set of three bars in Figures 3 and 4 depicts these results. Notice that for the deepening cluster results shown in Figure 3 the combination approach did marginally worse (i.e., recall+precision = 1.30 for the combination approach vs. 1.33 for the single best model), but for the widening clusters shown in Figure 4, the combination approach did a bit better (i.e., recall+precision = 1.49 for the combination approach vs. 1.42 for the single best model).

Discussion

These results, while preliminary, are very encouraging. It appears that the DOCE algorithm is reasonably capable of finding examples of the creative widening of a conversation, given prior, annotated examples of such reasoning in earlier discussions. Furthermore, as long as the researcher or teacher is careful not to use too-large model graphs against too-large discussion maps, the DOCE algorithm runs in a practical amount of time. Thus, the DOCE algorithm is a tool that either a researcher or a teacher can use to pinpoint and evaluate indicators of creative reasoning in the context of real e-discussions. The rigor imposed upon qualitative discourse analysis by the use of DOCE algorithm has already proved useful in iteratively refining the essential nature of creative widening in e-discussions. This technique has the potential to inform moderators when widening associated with creative thinking and deepening associated with critical reasoning is occurring in maps, as well as when it is not occurring and thus indicating an opportunity for a teacher to intervene. From analysis of the maps and from critical event recall interviews with participants, it appears that both oppositions and open questions serve to open up reflective spaces in which new insights emerge.

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Analyzing CSCL-mediated Science Argumentation: How Different Methods Matter

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Abstract: Research on argumentation has increased our understanding of knowledge construction, group learning, and scaffolding structures in CSCL although analyses of argumentation pose many difficulties. This could be due to the many theoretical positions that can be taken when approaching discourse data. In this paper, we use three popular analytic methods (interactional, content-specific, and linguistic) to compare the same fragment of scientific argumentation by Grade 4 children in Singapore. We show the complementary emphases and strengths of each disciplinary position as well as their weaknesses. The results imply that analytic methods arising from different disciplinary positions can potentially broaden our overall understanding of using argumentation in CSCL.

Introduction

Argumentation is an important research problematic in CSCL. Perceived to be a key feature in promoting deep understanding through group learning, CSCL studies have generally focused on the potential of technology to support productive argumentation (Andriessen, 2006). Invariably, studies on argumentation have focused on student discourse (e.g., Mirza, Tartas, Perret-Clermont, & De Pietro, 2007; Schwarz & De Groot, 2007; Weinberger & Fischer, 2007), and hence analysis often makes use of turn by turn interactional methods. However, there are other theoretical positions of interest such as the content-specific and the linguistic positions. For example, science educators are mostly interested in the construction of scientific arguments and development of concepts that are consistent with the established science community. Analysis of students' science argumentative discourse thus focuses on the substantive *content* of discourse rather than its *process* (e.g., Kelly, Regev, & Prothero, 2008; Sandoval & Millwood, 2005, 2008; Simonneaux, 2008). Linguists, on the other hand, favor the organizational structure of the argumentative genre and analysis here takes place at a more macro level of textual structure.

These theoretical positions that range from micro-genetic turn-taking to macro-structural levels of organization of content do present difficulties of analyses when using a popular framework like Toulmin's Argument Pattern (TAP). These problems include identifying the unit of analysis and differentiating the components in the framework (e.g., Erduran, 2008). While we are aware that each method of analysis will yield useful results, we seek to determine what these divergences are and how they together contribute towards a fuller picture of argumentation. In the following, we discuss an argument framework based on TAP and apply three popular methods of analyses—Interactional, Content-specific, and Linguistics—to study the same fragment of scientific argumentation among three Grade 4 students in Singapore. We found that the different and incommensurable units of analysis inherent when using the three frameworks resulted in alternative categorizations of students' ideas. Our findings broaden our overall understanding of using different analytic methods when studying argumentation in CSCL.

Theoretical Framework

In this section, we discuss different definitions of an argument and an argument framework based on Toulmin's Argument Pattern from different theoretical lenses. The purpose is to show how different theoretical positions may affect the analytical lens taken in studying a piece of argumentative discourse.

An argument can be considered a product and a process, constructed individually or socially (Jimenez-Aleixandre & Erduran, 2008). It is an individual production if we think of it as a piece of reasoned discourse. For example, a scientific argument is a particular genre produced by a scientist to convince others of his/her point of view. It is characterized by unique rhetorical structure and organization, defined by the social practice of science community (Scheppegrell, 2004). To achieve scientific literacy, in this case, is to be able to produce the rhetorical features in persuading and convincing others of one's point of view.

An argument can alternatively be thought of as a social process if we consider it as a chain of reasoning or different positions that people can adopt. While the second definition is often associated with opposition and aggression, and often considered as interference to learning, collaborative argumentation can be a powerful vehicle in developing critical thinking (Andriessen, 2006). It offers an opportunity for individual ideas to be externalized and challenged, leading to refinement of ideas and deeper understanding. In science, the social process of argumentation had allowed ideas such as the Plum-pudding model of an atom to be challenged as new evidences were brought in to refute it, leading to refinement of the theory to what is presently known as the

Rutherford's planetary model of atomic structure. In other words, argumentation is an important process of knowledge building. Since arguing is a form of inquiry, it is considered a form of learning (Koschmann, 2003).

A third perspective of argumentation comes from specific content disciplines such as science education. A key focus here is the development of conceptual understandings similar to the acceptable norms of the scientific community. Argumentation is perceived as one important means for this goal as its social nature allows students' cognitive processes to be made public so that any misconceptions can be clarified to align students' thoughts with the scientific community (Jimenez-Aleixandre & Erduran, 2008).

Argumentation Framework

A framework commonly used to study argumentation is Toulmin's Argument Pattern (TAP) which describes the structure of an argument as a set of interconnected claim, evidence, warrant, backing, qualifier and rebuttal. A claim is defined as a statement of assertion put forth for public acceptance. Evidence is a piece of specific empirical or theoretical data used to support a claim. Warrant, backing, qualifier and rebuttal are parts of reasoning to provide a link between a claim and a piece of evidence. However, this six-element framework is very complex to those applying this model to analyze the form and structure of arguments (Williams & Colomb, 2007; Erduran, 2008). Instead, a three-element framework, *claim – reasoning – evidence* (C-R-E), proposed by Williams & Colomb (2007) simplifies the original framework to capture the essential dimensions of an argument without separating its components too finely. Nonetheless, other problems still persist such as distinguishing the components of C-R-E: What counts as claims, evidence and reasoning? Another problem lies in the difficulty in identifying the unit of analysis: Is it a clause, turns of talk, or the whole text? These problems often lie with the different theoretical positions in analyzing an argumentative discourse as we now explain.

From a linguistic lens, analysis of genre takes a *grammatical* approach. Analysis involves studying the use of language resources in the construction of a text to look for language patterns and organizational structure of the genre (Derewianka, 1996; Painter, 2001). For example, an argumentative text will consist of predictable features such as the use of connectives and purpose circumstances such as *first, second, so that, as a result, and because*. Therefore, the unit of analysis for studying genre should be at a micro-genetic clause level, conducted for each turn of talk.

Unlike this linguistic micro-genetic approach, a social theorist takes a more macro approach towards discourse analysis (Sawyer, 2006; Stahl, 2006). Taking each turn of talk as its unit of analysis, interaction analysis looks at the *social function* of each turn of talk between interlocutors. Interaction analysis categorizes each turn of talk by taking into consideration the previous and next turn of talk. The I-R-E (initiation-response-evaluation) is a typical example of an interaction analysis of classroom discourse.

While the above two methods of analyses focuses on the processes and functions of each turn of talk, discipline-specific educators are more focused on the achievement of *content-based learning* outcomes. For example, science educators are concerned whether students acquire the same set of ideas consistent with the scientific community or the extent to which student talk resembles the structure of a science argument. Analysis now involves studying the types and quality of knowledge in an argument. For example, Sandoval and Millwood (2005) looked at how students coordinated data and science knowledge to justify their claims. The unit of analysis for dialogic argumentation is the individual utterance where content is emphasized.

To summarize the three analytic methods (i.e. Linguistics, Interactional, and Content-specific), each analysis method has its own focus and hence, the unit of analysis differs. When these methods are applied to the *same* fragment of online argumentative dialogue, we show (1) the differences in outcomes, and (2) what strengths/opportunities and limitations/threats arise in each. In the next section, we will give a brief account of the background of the online discussion that is being analyzed.

Method

In this study, we applied three methods of analysis to the same fragment of discourse among three elementary school students and their teacher. This discourse is part of an online discussion whereby the three students (Henry, Yvonne, Mary) were discussing how the presence of plankton and algae in a reservoir affects the amount of dissolved oxygen in the water. This discussion is a follow-up activity where they previously collected data on water turbidity and made observations about the types of organisms found there. The online discussion platform used, Knowledge Forum, is an asynchronous CSCL system that supports students' collaborative discourse through public display of ideas to encourage intersubjective meaning making (Scardamalia & Bereiter, 2003).

Findings and Discussion

This section reports the analysis of online discourse among the students and their teacher using different analytical lenses: (1) Linguistics, (2) Interactional, and (3) Content-specific. It also discusses the strengths and limitations of the three analysis methods in helping us make sense of a discourse from an argumentative framework.

Comparison of Coding Results using Different Analysis Methods

The online discourse is taken from a thread of discussion centered on Henry's response (note 2) to the question posed by the teacher (note 1). Table 1 shows the coding of this discussion thread using different analysis approaches.

Table 1: Coding of online discussion thread.

Note	Author	Content	Coding based on different analytical lens		
			Linguistics	Interactional	Content-specific
1	Teacher	I need to understand How the presence of plankton and algae may affect the quality of water (amount of oxygen)?	Question seeking causal explanation	*Questioning*	*Questioning the manner of a process*
2	Henry	The algae floats on top of the water and blocks sunlight from getting into the depths of the water	Stating cause – effect	Responding with certainty	Giving Reason
3	Yvonne	I need to understand how will the algae floating on the top of the water affect the amount of oxygen?	Question seeking causal explanation	*Questioning*	*(Question seeking claim)*
4	Mary	Maybe the algae prevent the air from escaping	State effect (with hedging)	Responding with uncertainty	Giving Reason
5	Teacher	I need to understand how does algae prevent air from escaping?	Question seeking causal explanation	*Questioning*	*(Questioning the manner of a process)*
6	Mary	My Theory the algae takes in the air that is going up to the surface of the water	Stating cause	Responding with certainty	Giving Reason

When a linguistic lens is used to study the turns of talk, it shows that the genre of each turn of talk is mainly one of explanation. The participants in this discourse were trying to construct a causal explanation for the effect on the quality of water caused by the presence of plankton and algae in the water (see Note 1). The resulting notes (2, 4 and 6) were trying to address the question with supporting questions seeking further elaboration of the effects or the causes resulting in the phenomenon. For example, in Note 2, Henry attempted to explain how the location of the algae results in sunlight being blocked. However, he did not go further to describe the effect on the amount of oxygen as a result of sunlight being blocked. This could be the reason why Yvonne asked for further causal effect on the amount of oxygen when "the algae floating on top of the water" (Note 3). Therefore, in these few turns of talk, the purpose of each turn is to elicit or give a causal explanation for the phenomenon raised by the teacher in Note 1.

Through the lens of interaction analysis, the interaction pattern was mainly question-answer. This is evident in the excerpt whereby each question (Turns 1, 3 and 5) was immediately followed by a response, which in turn, was followed by another question.

From a content-specific perspective, in which the accuracy of content and argumentative structure is important for achieving the learning outcomes, an expected model answer to the teacher's question in Note 1 is as follows, with the idealized structure of a science argument identified in brackets.

> The presence of plankton and algae in the water reduces the amount of oxygen in the water *(claim)*. This is evident by the low oxygen level measured in water with lots of algae and plankton found *(evidence)*. This is because when plankton and algae fill the water, photosynthesis cannot occur as they block sunlight from reaching the water plants at the bottom of the reservoir. Besides, algae and planktons also respire, taking the oxygen in the water. *(reason)*

In this analysis, categorization of ideas was made in relation to the question initiated by the teacher in Note 1. Since the question required the students to make a claim that connected the presence of microorganisms (plankton and algae) and the amount of oxygen in the reservoir, students' ideas were coded as a claim if the students' note related the microorganisms to the amount of oxygen in the reservoir. An idea was coded as evidence if some empirical data was put forth. Any scientific principles or theories that related the microorganisms with light and photosynthesis were considered as reasons. With this form analysis, we found that the ideas put forth by the students were mostly reasons. Ideas in Notes 2, 4 and 6 were describing how algae affects sunlight going into the depth of the reservoir (Note 2), which is essentially the principle of light not able to penetrate through opaque objects, and the condition needed for living things (Notes 4 and 6), which is based on the conditions for living things to survive. In relation to the question asked in note 1, there were no explicit claims made about how these processes may affect the amount of oxygen in the reservoir even though Note 3 seemed to be eliciting for one. There was also no mention of any empirical data collected from the reservoir.

In short, we found that the coding results of an argumentative discourse arising from different analysis methods provided different information about the discourse taking place.

Strengths and Weaknesses of the Three Analytic Methods

The findings of this study show that different analysis methods resulted in different coding results. While each analytic method has its strengths, the different foci also limited what it reveals of an argument. From a linguistics approach, we see the structural form of the argumentative discourse constructed by the students. It revealed which components of an argument are co-constructed by the students and which aspects of an argument were still lacking. For example, the discourse among the three students was made of mostly personal responses about the causes that affect the quality of water. However, they did not identify the eventual effects of the presence of microorganisms on the quality of water. If the intent of the online discussion was to provide the platform for science argumentation, the resulting explanatory genre demonstrated in these turns of talk shows the commonsense knowledge that students tend to use when they have not mastered the rhetorical structure of a scientific argument. From a cultural perspective, these students have not been inducted into the social practices of the science community (Scheppegrell, 2004). In other words, a linguistic approach to analysis is useful in informing the extent in which students have appropriated the social norms of communication within a particular community. Such findings are useful in providing information of the kinds of technical scaffolds needed to induct students into the social practice of the community. Limitations of a linguistics approach lie in its lack of focus on interpersonal relationship and correctness of discipline-specific content in the co-construction of knowledge. Understanding these aspects is better informed by interactional and content-focused methods.

While the linguistic approach provided information about the structure of the argumentative discourse, the interactional method informed the process of meaning making among the students. It revealed the role of each note in the co-construction of an argument. For example, the analysis of the three students' interaction showed that the students were merely responding to each question put forth individually. While each question attempted to elicit an elaboration of the previous response, it was answered by the students in isolation, without attempting to connect with previous responses from others. This lack of connection or elaboration of answers made each response appear like a claim, which could be further challenged or questioned. The superficial notes could be a reason for the failure to sustain a discussion (Hewitt, 2005). From this example, it shows that an interactional method is useful in revealing the process of meaning making (or the lack of it). This information is useful for designing scaffolds to help students construct a more in-depth argument with their ideas so that a more sustainable discussion can go on. The limitation of an interactional analysis shows that the types of knowledge and depth of explanation are not well understood. A content-specific method is thus more useful for this purpose.

The findings from a content-specific approach show how students made use of very specialized forms of knowledge appropriate for a particular community. For example, in the sample online discourse, it showed that ideas put forth in Notes 2, 4 and 6 were based on scientific facts and extending it to the process in which they will affect the environment conditions such as "algae … blocks sunlight from getting into the depths of water" and "the algae takes in air". While these may be considered as claims by themselves, they are also reasons when analyzed in respect to the questions asked in Notes 1, 3 and 5 as the ideas explain the process which will affect the amount of dissolved oxygen in the water. However, there were no explicit claims made about the amount of dissolved oxygen in the water in the presence of algae and plankton. This could be the case where students were more confident in putting forth knowledge they knew empirically or from past experience rather than threading on new grounds (i.e., making new claims). Results of a content-specific approach are, therefore, helpful in identifying the types of knowledge that students' ideas draw from, which in turn, inform the epistemic beliefs of the students (Sandoval & Millwood, 2008). Such findings are helpful in directing how intervention could be applied to help students make use of different sources of information, including their own beliefs, in knowledge building. The limitation of content analysis is that it does not capture the textual organization of an argument or the social process of knowledge building.

Conclusion

In this paper, we demonstrate the different aspects of an argument through a short fragment of online discourse, uncovered by different analysis methods: linguistics approach informs structural organization, interactional approach informs the process of co-construction of the argument and content-specific approach informs the types of knowledge used in forming the argument. Adopting one method solely or exclusively presents a partial picture of how an argumentative discourse brings about knowledge building. Our findings highlight the necessity in having multiple analytic lenses when examining complex data in CSCL. Together, these three analytical lenses have the potential to broaden our understanding of how argumentation can be used as a valuable form of knowledge building in CSCL.

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Learning as a Practical Achievement: An Interactional Perspective

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Abstract: Despite the definitional difficulties associated with learning and instruction, they evidently occur as social realities for those involved in the practical, day-to-day work of learning and instructing. In this paper we offer an interactional perspective of learning and instruction by relying on the commonsense recognizability of learning to investigate what participants themselves do to achieve and recognize learning's work.

Introduction

Learning as a cognitive process seems to be properly the domain of psychology, education and cognitive science - and so it is, but not exclusively so. Learning and other cognitive activities are also properly matters for investigation as phenomena of social interaction (Schegloff 2006, Heritage 2005, 1984, Coulter 1989, Suchman 1987). As such, learning is understood to be both a "social" and a "psychological" fact. In this essay, however, we leave the psychological facticity of learning to those who are best equipped to study it. We are concerned with learning as a social fact, as a phenomenon that is recognizable and doable in and through interaction. While it may seem odd, thinking of phenomena such as learning in social interactional terms can be a source of significant insight (cf. Schegloff 2006, Drew 2005, Heritage 2005, Coulter 1991). In particular, we recognize in commonsense usage and in actual practice that learning is constituted through the work of assessment. In other words, instructors or others constitute learning in and as the work of assessing certain kinds of observable and assessable actions of the "learner" (Mehan, 1979). Learners and instructors alike routinely treat learning as an esoteric phenomenon, something hidden from view, something attributable as an achievement of an actor based on the observed and observable performance of that actor but which, in itself, is treated as unobservable. This is a view aligned with traditional theories of learning that treat learning as a hidden and inferred process taking place exclusively "inside the learner" (Simon, 2001).

We treat learning as a post-hoc achievement, through and as the outcome of the process of its recognition. It is in the way that changes in cognitive states are performed *for assessment* that learning is achieved. While circumstances in which instruction occurs provide a focus for a set of activities associated with teachers and students, masters and apprentices, knowledge transfer and the like, learning is informally understood for the purposes of this paper as the work that actors do to achieve displayable, demonstrable and assessable competence. This involves both the practiced accomplishment of proper action and the demonstrable performance of proper action *for purposes of assessment* (whether self- or other-assessment). The demonstrable and assessable performance of proper actions only becomes recognizable as a learned achievement as a post hoc outcome of the assessment transaction.

The CSCL Context

The data for this analysis derives from logs and recordings of online synchronous chat interactions among students working as peers to collaboratively address and solve mathematics problems. These data were acquired over a three year period as part of the Virtual Math Teams (VMT) project at Drexel University (Stahl, 2009). They represent a mix of various online chat technologies including AOL's Instant Messenger ™ and VMT Chat, an online system developed in collaboration with Fraunhofer Institute IPSI in Germany with both chat and whiteboard capabilities (Mühlpfordt & Stahl, 2007). This CSCL environment provided us a perspicuous setting in which learning is "made visible" (Stahl, 2002) as a practical achievement of learners that is "observably and accountably embedded in collaborative activity" (Koschmann, 2001, p. 19). In particular, our analysis focuses on excerpts obtained from the VMT corpus where participants reflexively display their orientation to learning as a members' matter through their situated actions (Garfinkel, 1967; Suchman, 1987).

Learning as a Practical Achievement

In a seminal CSCL study Roschelle (1992) characterized learning as an interactive process where incrementally developed understandings lead to convergent conceptual change. Although a distinguishing feature of CSCL research is its consideration of learning as a fundamentally social phenomenon, even the paradigmatic CSCL studies characterize learning in reference to changes in hidden structures and/or cognitive states (Koschmann, 2002). In interactional terms however, studying the particular ways in which changes in cognitive state are marked by participants can help analysts eliminate references to such hidden structures. In the context of joint activity not only change-of-state markers are used, but assessable actions are performed. In particular, these actions are performed for the purposes of being assessed. To see this, we use methods of Conversation Analysis to describe in detail the interactional organization of the phenomena in which we are interested. One example of this is provided in Figure 1.

In Figure 1, Quicksilver uses 'Oh…..” at 7:27:01 as a change of state display token (Heritage, 2002) to inform other participants that the change in his cognitive state was relevant to the ongoing interaction. This is followed at 7:27:05 by a formulation of the achieved 'understanding,' produced as a text posting, for others to assess for it's “correctness” or adequacy: “so that is the bottom level”. Finally, Quicksilver self-assesses with “I get it” at 7:27:06. Prefacing the display of an achieved understanding with “so” also serves to indicate that it is derived from or is a consequence of a nominally unobserved cognitive process. Thus, Quicksilver (a) made available a change in cognitive state, (b) formulated an understanding for others to receipt and assess, (c) presented this effort as a private experience, and (d) offered a self-assessment as well.

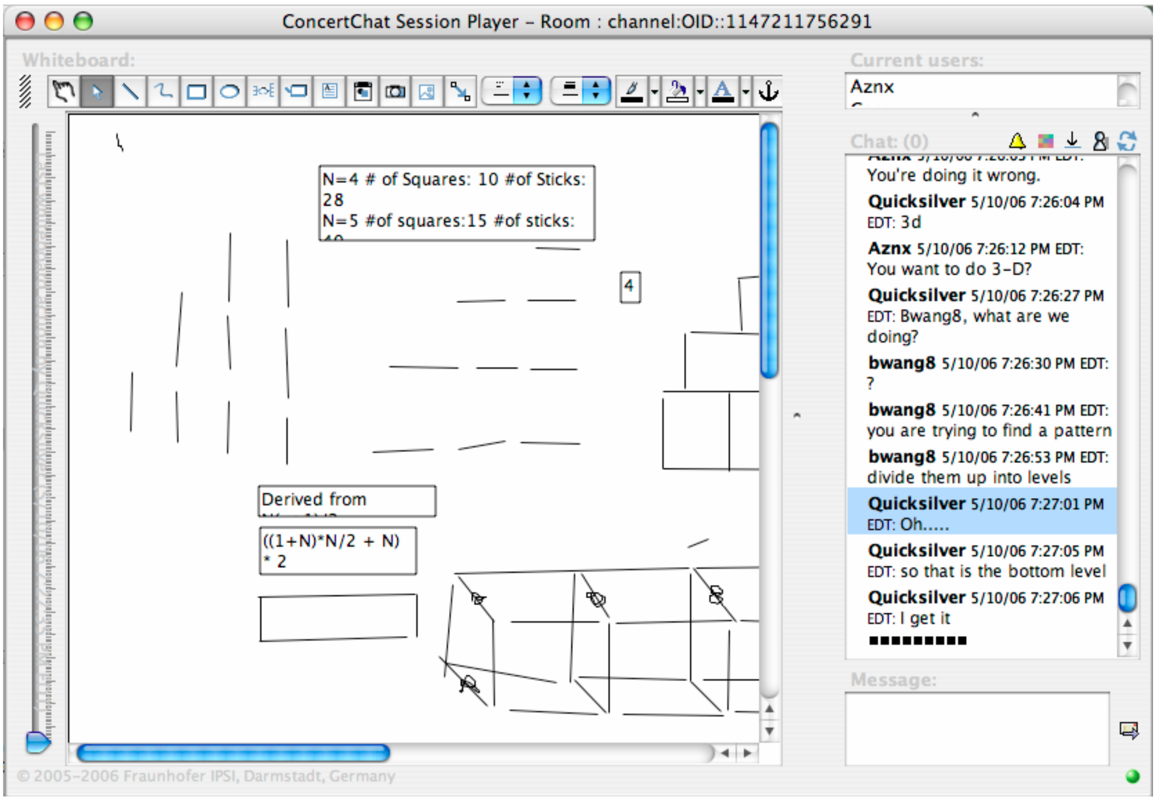

Figure 1.

In the next example (Figure 2), we see how a member's timely contribution to a sequentially unfolding display of reasoning is treated as a demonstration of competence and cognitive achievement by the other member through a post-hoc assessment.

Line	Handle	Posting	Time
26	davidcyl	the nth pattern has n more squares than the (n-1)th pattern	18:27:32
27	davidcyl	Basically it's 1+2+..+(n-1)+n for the number of squares in the nth pattern	18:27:55
28	137	so n(n+1)/2	18:28:16
29	davidcyl	and we can use the Gaussian sum to determine the sum: n(1+n)/2	18:28:24
30	davidcyl	137 got it	18:28:36

Figure 2.

In Figure 2, members are oriented to the task of finding a formula to summarize the number of squares in the n^{th} stage of a geometric pattern. Davidcyl describes how the number of squares changes between the $(n-1)^{th}$ and n^{th} stages at line 26. In the next line he expands his description by providing a sum of integers that accounts for the number of squares required to form the n^{th} stage. As Davidcyl composes a next posting, 137 posts a so-prefaced math expression at line 28, "So n(n+1)/2" that (a) shows 137 has been attending to the organization of Davidcyl's ongoing exposition, (b) displays 137's recognition of the next problem solving step projected by prior remarks, and (c) call on others to assess the relevance and validity of his claim. Davidcyl's message at line 29 is a more elaborate statement that identifies how his prior statements, if treated as a Gaussian sum, yielded the same expression 137 put forward at line 28 (viz. "n(n+1)/2"). Given that 137 anticipated Davidcyl's Gaussian sum, Davidcyl announces in the very next posting that "137 got it," treating 137's production of the Gaussian sum as evidence that 137 had competently understood Davidcyl's exposition in lines 26 and 27.

In the next excerpt (Figure 3), a change of cognitive state is marked by the presentation of a self-assessment of a series of claims and whiteboard actions. In particular, self-assessment is used as a form of *repair* to mark a change in the cognitive state of the actor making the claims and the assessment.

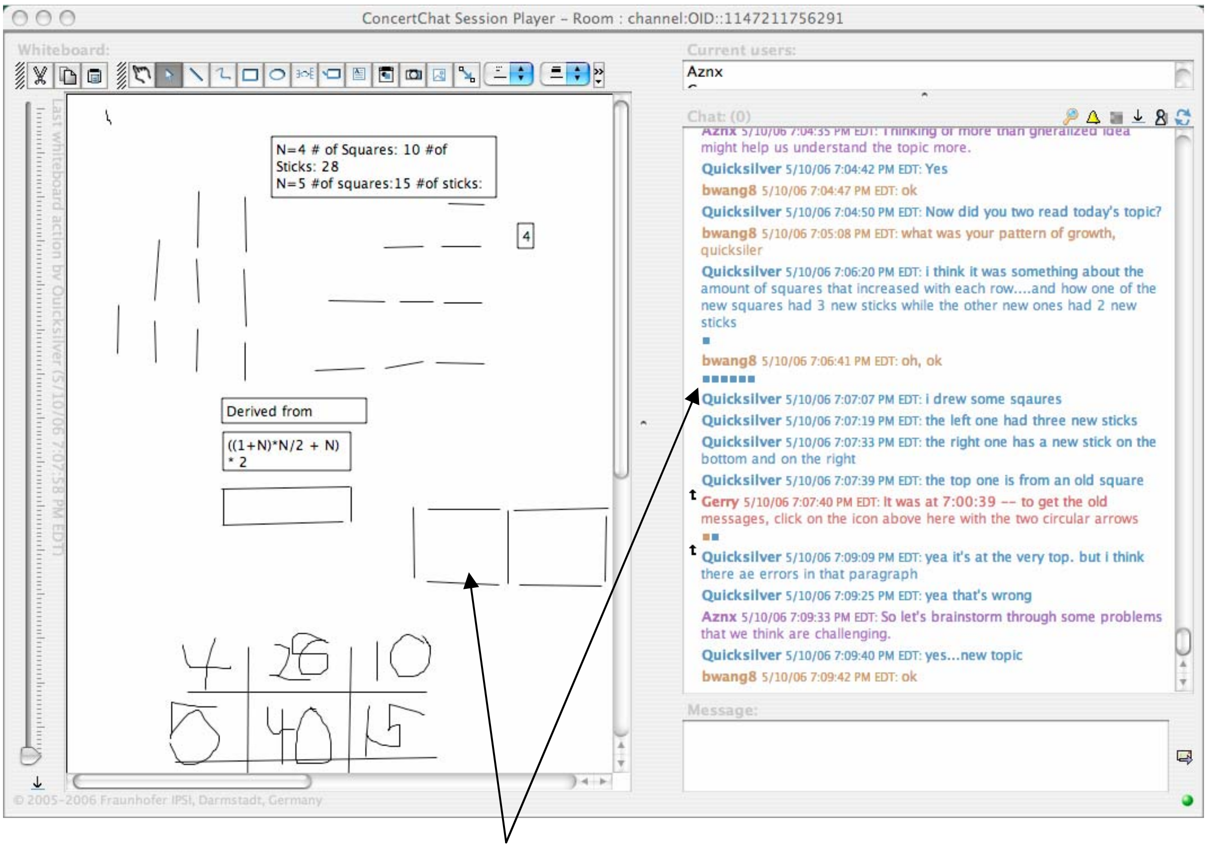

Figure 3: Blue squares in the chat correspond to Quicksilver's drawing actions (marked with the left arrow)

The whiteboard activities performed by Quicksilver serve as a specific example of his post at 7:06:20 that provides for the relevance of his subsequent postings. What follows then is an extended sequence of postings produced by Quicksilver at 7:07:07 through 7:07:39. These postings present the sequential organization of reasoning provided in the first posting by making reference to a specific illustration on the whiteboard. When an actor produces an alternative version of a prior account (Cuff, 1993), the alternative version can be seen in certain circumstances as evidence of an alternative cognitive organization of the matter being described and an effort to effect a change in the cognitive state of recipients (including, possibly, the author of the alternative version). Then, at 7:09:09 and 7:09:25, Quicksilver produces a self-assessment in which he displays his recognition that there is a problem with his versions of a pattern of change. This admission of error is reminiscent of self-repair work in that the author of the "incorrect" account marks it as incorrect. This self-assessment also marks a change of cognitive state. That which was presented and treated as a possible solution is now rejected as incorrect in a way that implicates a change in Quicksilver's "thinking" about the matter. While it is interesting that no one offers an alternative version of a pattern of change at this point, the work done to put forward this initial version and its assessment by the author of the version provide evidence not only of changes in cognitive states but also of learning's work.

In the next excerpt (Figure 4), we will see an example of other-initiated repair where one group member offers a correction to a claim previously made by another member, and how the resolution of the difference in opinions produces a learning moment for one of the members.

Line	Handle	Posting	Time	Duration
192	AVR	for the 9 triangle it's about 7.79	8:42:45	0:00:06
193	AVR	and for the 12 it's 10.39	8:42:55	0:00:10
194	PIN	the height?	8:43:02	0:00:07

195	AVR	yes	8:43:06	0:00:04
196	AVR	now LET ME CALCULATE THE AREAS	8:43:18	0:00:12
197	PIN	for the 9	8:44:28	0:01:10
198	PIN	you did it wrong	8:44:30	0:00:02
199	PIN	its 8.352	8:44:36	0:00:06
200	AVR	no	8:45:13	0:00:37
201	PIN	ya	8:45:25	0:00:12
202	AVR	in the triangle a = 4.5	8:45:26	0:00:01
203	PIN	cuz look	8:45:27	0:00:01
204	PIN	ya	8:45:28	0:00:01
205	AVR	and b = 9	8:45:29	0:00:01
206	PIN	4.5 squared is 20.25	8:45:43	0:00:14
207	PIN	20.25 =X=81	8:45:53	0:00:10
208	PIN	20.25+X=81	8:46:06	0:00:13
209	AVR	yeah	8:46:08	0:00:02
210	AVR	right	8:46:16	0:00:08
211	PIN	X=60.75	8:46:24	0:00:08
212	AVR	exactly	8:46:27	0:00:03
213	PIN	the square toot of that is	8:46:30	0:00:03
214	PIN	7.794	8:46:40	0:00:10
215	PIN	oooppps	8:46:42	0:00:02
216	AVR	right...	8:46:43	0:00:01
217	PIN	my fault	8:46:44	0:00:01
218	AVR	MUAHHAHA	8:46:50	0:00:06
219	AVR	WHO PREVAILS NOW	8:46:53	0:00:03
220	AVR	no jk lol	8:46:56	0:00:03
221	PIN	me	8:46:57	0:00:01
222	AVR	sorry	8:46:57	0:00:00
223	PIN	jk	8:46:59	0:00:02
224	AVR	okay	8:47:05	0:00:06

Figure 4.

In this excerpt the group members are oriented to the task of calculating the height of two equilateral triangles of length 9 and 12 respectively. At the beginning of the excerpt AVR presents her findings for each triangle. At 194, PIN asks whether the provided numbers correspond to the height values. PIN's question marks that AVR's results are somehow unexpected or problematic and provides AVR an opportunity to do self-repair. In line 195 AVR acknowledges that the numbers she provided are height values. Then in line 196 she announces that she is ready to move on to the next calculation. In 198, PIN explicitly disagrees, calling what AVR did "wrong". Then in line 199 he offers a repair for the problematic value. 37 seconds later AVR disagrees with PIN. The emergence of this conflict opens a sequence of exchanges where AVR and PIN step each other through the derivation of the height value for the first triangle. First, the side values relevant to this operation are offered by AVR in lines 202 and 205. Then, starting in line 206 both actors organize their exchange in such a way that as soon as PIN performs the next step of the calculation AVR provides an immediate assessment of that step. This exchange continues without any interruption until PIN carries out the last step of the computation in line 214, where he ends up with a value very close to what AVR proposed at the beginning. Line 215 indicates that a shift in PIN's cognitive state has occurred, and finally in line 217 he makes the self-assessment that he was mistaken. In other words, the work that PIN does to demonstrate his position and the recognition that his demonstration yielded an answer different than he initially proposed have produced a learning moment for him.

Discussion

While learning is often treated as a change of an individual's internal cognitive state, we take the position that learning is a social fact. In other words, learning is the full set of interactional procedures by which actors (a) assert, display and enact competencies and (b) allocate matters such as knowledge, understanding, etc., to each other. In this essay, we turned our attention to the work actors perform to display actions for assessment and the assessment work those actions solicit. In a preliminary way, our analysis has shown that interior/private change is attributed to actors based on simple claims of competence or observable displays and enactments of competence as methods of attributing learning's work to actors . When simple claims are made without any enactment of competence, the attribution of learning tends to be weaker and more susceptible to challenge than claims accompanied by enactments of competence (Pomerantz, 1984). When displays and enactments of competencies are presented, learning as achieved understandings and competencies can be more strongly attributed to actors. This is predicated on the notion that learning and understanding themselves are unobservable and only the demonstrable performance of competent action by actors who somehow "possesses" that learning or understanding is available for public inspection.

When an actor posts a statement like "Eureka, I understand!" or "ok, I get it", he or she claims a change in cognitive state in a very public manner but does not demonstrate that change. For instance, the use of the oh-preface in the very first excerpt demonstrates a method for presenting a claim as though it were the outcome of a private or unobservable process (Heritage, 2002). The claim of changed cognitive state may simply be accepted as adequate without the learner having to enact an actual competence. While we know that actors often attribute learning to actors who only make claims of changed cognitive state without any displays of competence, we have observed in our analysis that so- and oh-prefaced claims (a) make displays of competence interactionally relevant as expansions following the production of such markers of cognitive change, and (b) that such displays of competence provide and serve as stronger evidence of learning and understanding (Pomerantz, 1984). The critical feature here is that when an actor displays or enacts a competence for assessment (as we have seen above), he or she not only makes a stronger learning claim, but treats learning as a social matter to be ratified by other competent actors in the scene. Hence, assessable displays and enactments of competence are important constituents of learning's work. Of course, the other part of learning's work, as we have shown, is the assessment of these displays of a learner's competence. It is only upon the competent assessment and ratification of a learner's competence, either with or without an actual display of that competence, that learning is attributed to the learner. It is in this sense that we claim learning, as a social fact, is a post hoc achievement of learning's work.

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Examining the Relation between Domain-Related Communication and Collaborative Inquiry Learning

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Abstract: Research has suggested that providing elaborated explanations is often more beneficial for learning than receiving explanations (e.g., Webb, 1989). Applied to chat communication in a collaborate inquiry learning environment, we would expect that in a dyad the learner with more domain-related contributions than his partner would learn more. In the paper we develop a method to examine the relation between domain-related chats and learning outcome for intuitive knowledge. We describe how we automatically extract domain-related messages, and score them based on the expected cognitive effort to produce the messages. The analysis confirms that there is a positive relation between a high score on domain-related chats and the learning improvement as measured by the difference between a post-test and a pre-test on intuitive knowledge.

Introduction

In a collaborative learning setting two or more students share and construct knowledge while they work towards the solution of a problem or assignment. Research has shown that collaboration between students may enhance learning (Lou, Abrami, & d'Apollonia, 2001; Slavin, 1994; van der Linden, Erkens, Schmidt, & Renshaw, 2000). Inquiry learning environments are very suitable for collaborative learning. In a simulation based inquiry environment students learn through experimentation and scientific reasoning. The interface of the learning environment allows students to change input variables and observe the effects of their actions. Students learn about the principles and rules of scientific phenomena through processes like hypothesis generation, experimentation, and conclusion (e.g., de Jong & van Joolingen, 1998). During inquiry learning, students must make many decisions (e.g., which hypothesis to test, what variables to change) and in a collaborative setting, the presence of a partner stimulates students to make their plans and reasoning about these decisions explicit.

To maintain a successful collaborative working relationship, ideas and theories must be externalized and explained in a mutually understandable way for the partners in the collaborative learning group (Teasley, 1995). Through externalization students express and explain ideas, ask for clarifications or arguments and might generate new ideas. The process of making ideas public through externalization and explanation, stimulates students to rethink their own ideas and might even make them aware of possible deficits in their reasoning (van Boxtel, van der Linden, & Kanselaar, 2000). Research indicates that the degree of participation in collaborative activities is related to group performance as well as students' individual learning.

Protocols recording collaborative learning can be analyzed from several perspectives. They have been analyzed in terms of students' degree of participation, communicative activities such as arguments and elaborations (van Boxtel et al., 2000), different learning processes (Hmelo-Silver, 2003; Saab, Van Joolingen, & Van Hout-Wolters, 2005), or the exchange of domain-related information (Van Drie, Van Boxtel, Jaspers, & Kanselaar, 2005). In this study we focus on the collaborative construction of domain-related knowledge, by examining the communication protocols of dyads who together interacted with a collaborative inquiry learning environment. Within a dyad, students may not only differ in their overall degree of participation (Cohen, 1994), the characteristics of students' contributions may also differ. For the collaborative construction of domain related knowledge it seems important that students not only actively participate in the chat discussion but also share and exchange domain-related information in their dialogue.

Being interested in domain-related knowledge construction, our focus is on students' externalizations of domain-related conceptions and their interpretation of information obtained from the learning environment or provided by their partner. More specifically, we are interested in the degree of domain-related information each partner contributes to the dialogue. From earlier studies on collaborative learning we learn that, for example, providing elaborated explanations is often more beneficial for learning than receiving explanations (e.g., Webb, 1989). This can be explained by the fact that students who are providing elaborate explanations are actively engaged in externalization processes, which probably stimulates acquiring new knowledge. However, not only explanations can be beneficial for learning together.

Research question and hypothesis

Based on the considerations presented above, this study examines how students' domain-related contributions are related to their individual learning outcomes. The simulation-based inquiry learning environment used in this study requires students to focus on relations between variables in the domain. It is expected that within a dyad, a student who externalizes a higher proportion of domain-related knowledge in that dyad than the partner, reaches a higher post-test score than students who externalize less domain-related knowledge during the learning session.

Method

Learning environment and task

Students worked in dyads with an inquiry learning environment that was based on a computer simulation of colliding objects. The main task for the students was to discover the laws of physics underlying the simulation. The learning environment consisted of four simulations accompanied with assignments that presented the learners with small research questions to guide their inquiry learning process. A total of 35 assignments were available in the learning environment. Dyads worked collaboratively on two separate computers with a shared interface and communicated through a chat channel (based on Microsoft Netmeeting technology).

Tests

Students' individual learning outcomes are assessed with two domain knowledge tests, a "definitional knowledge" test focusing on facts and formulae, and a "what-if" test for intuitive knowledge on relations. Each question of the "what-if" test consists of three parts: condition, action and prediction. First a condition/situation before a collision is presented to the students. Subsequently, the action (for example, a collision against a fixed wall) is presented. Finally, three predicted states are presented to the students either in text or pictures. Students are asked to select the state that follows from the action in the given condition. The definitional knowledge test as well as the "what-if" test was computer administered and pre- and post-tests were parallel versions of the same test.

Participants

Dyads were heterogeneous with respect to students' school achievement in the domain of physics (this information was provided by the participating schools). This grouping was based on the finding that heterogeneous grouping is beneficial for both high and low achieving students (Webb, Farivar, & Mastergeorge, 2002). Students were paired with a student from their own class. Participants attended two sessions. In the first session dyads were composed and students practiced with a SimQuest practice simulation that allowed them to explore the features of the interface and work with the chat tool. The second session started with the two pre-tests, followed by 90 minutes of interaction with the simulation environment. At the end of the session students completed the post-test versions of the knowledge tests.

Determining learner contribution in dyads

The question we are addressing is whether there is a relation between the nature of the domain-oriented contribution of a learner and learning improvement. In this section we first give some examples of the interaction between learners, and then motivate our choice of how to develop a method that allows answering the research question. An example of an excerpt of the interaction between two learners called X and Y is:

1 12:58:48 X: if the mass becomes higher, the momentum decreases, I think
2 12:59:43 Y: no, that is not true
3 13:00:02 Y: p also is higher, have a look
4 13:00:03 X: experiment
5 13:00:16 **** Running a simulation****

Here X thinks there is a qualitative relation between mass and momentum: if the mass increases, the momentum decreases (line 1). Y, after about a minute, realizes that the relation is incorrect (line 2) and suggests that the momentum, the symbol p stands for momentum, increases when mass increases (line 3). X suggests to do an experiment to find out more (line 4) and runs the simulation. This brief example illustrates learners X and Y share their individual understanding of the domain and try to reach a joint understanding.

Excerpts like the one above are not very common. Below is an example, between learners P and Q, which follows a pattern that is much more frequent:

6 13:31:33 P: speed is the same after the collision
7 13:31:37 Q: yes

8 13:32:04 Q: 4
9 13:32:12 *** *Answer 4 is selected (it is incorrect)* ***
10 13:33:11 P: 1
11 13:33:25 Q: ok
12 13:33:29 *** *Answer 1 is selected (it is correct)* ***

P communicates a domain-related observation (line 6). Q immediately agrees (line 7) and after about half a minute proposes 4 as the correct answer (line 8), the answer is wrong (line 9). Then P proposes 1 as the answer (line 10), Q agrees (line 11) and the answer turns out to be correct (line 12). The pattern is that one of the learners exchanges a domain-related finding (line 6) and the partner only acknowledges this without referring to domain-related terms. Often the entire discussion then switches to what answer to give. If this happens repeatedly, P may at some point decide to give up formulating domain-related messages all together as Q does not appear to do anything with them.

In order to determine what the level of domain related contribution of each learner is, we introduce some abstractions. The level of domain-related contribution of a learner is denoted as the value D(learner). Based on the example excerpts above, we have $D(X) \approx D(Y)$ because X contributes one domain related statement (statement 1) and Y does the same (statement 3) and $D(P) > D(Q)$ because P contributes one domain related statement (statement 6) and Q does not contribute a domain related statement. It would perhaps be tempting to conclude that $D(X) > D(Q)$ and $D(Y) > D(Q)$, however, not allowed to conclude this. The reason is that the value of D(X) is dependent on the collaborate setting with Y, which we denote as $D(X|Y)$, while the value of D(Q) depends on the collaborative setting with P. If we would like to estimate the "true" value of D(X) in other collaborative settings then a better approximation is:

$$D(X) = \text{average}(D(X|Y) + D(X|P) + D(X|Q))$$

Given that we have no values for $D(X|P)$ and $D(X|Q)$, a better estimate of D(X) cannot be computed. The same goes for the other three learners in the example, and we can therefore not compute an estimate for any D(*learner*) that can be meaningfully compared with D estimates for other learners.

An intuitive example, for comparison purposes, is the idea of a marathon run. Two runners X and Y decide to beat the world record. They agree that during the first 35 kilometers Y acts as a pacemaker and runs in front. X wins the race in a record 2.03:00, Y finishes in 2.04:00. A year later, under precisely the same circumstances, P' and Q' also want to beat the world record, but P' and Q' do not make any prior agreements, each runs his own race, P' finishes in 2.03:30 and Q' in 2.04:30. All other things being equal, it is not allowed to conclude that P is faster than P' as their performance depends on having a runner they as a pacemaker or not. Though the conclusion is drawn in practice, otherwise there could not be a world record for the marathon, it is hardly justified and proposals to ban pacemakers from marathon is based on these considerations.

To summarize: it is not possible to obtain a good estimate for the value of the contribution of a learner in a dyad (or larger group of learners) that can be compared to other learners in other dyads in the same experimental setting. This result may be important for CSCL in general, as it points to a major methodological issue, and might also explain why previous research has not related individual performance to individual learning outcomes in a collaborative learning setting and why researchers carefully consider the composition of the dyads or groups (Webb, Nemer, Chizhik & Sugrue, 1998).

Does this prevent us from finding out whether the contribution measure, D(learner), is related to learning outcome? We think this is still possible by using an indirect method. Within a dyad, the learner with the highest value for the level of contribution measure is added to a group of learners called A, the other learner in the same dyad is added to a group called B. This is like a knock-out competition, the A's would be the winners the B's the losers. If the average learning outcome of the A's is significantly different from that of the B's, the level of contribution measure is the probable cause, because this was the reason for partitioning the learners into A's and B's.

Domain-related contributions

Partitioning learners into A's and B's, as proposed above, requires a measure of a learners' contribution to the dialogue, that allows us to do the assignment as being A or B. Inquiry learning environments, like the one used in this study, stimulate the acquisition of knowledge about relations in the domain. For example, in physics momentum is defined as $p = m * v$, where p is momentum, m is mass, and v is velocity. Learners can find out about these kind of relations by changing one of the variables and (graphically) inspecting the effect on the others.

Learners can share their thinking on the relations with their partner through the chat tool. To determine the level of domain-oriented content of a message, we distinguish three types of contributions:

- *Domain terms.* The use of domain terms, such as velocity, increases and the abbreviation v, transfers at least a certain domain focus by the learner. The message *shall we look at mass* contains one domain term.
- *Qualitative statements*. These are phrases containing both a quantity and a qualitative relation, for example *speed increases*, or *momentum is lower*. We do not make a distinction between qualitative statements that result from observation (*speed increases*) and qualitative statements that suggest future action (*shall we increase the mass*). All such statements demonstrate a clear domain focus.
- *Conditional sentences involving qualitative statements*. These are evidence of interpretations or hypotheses related to the domain. A conditional sentence is the grammatical construct which relates a condition to a consequence. In the collision domain, an example is *if the mass becomes higher, the momentum decreases*.

Analysis of the messages

Identifying the above three types of contributions in chat protocols, requires an analysis, or semantic interpretation, of the message. A human can, if the message is *velocity increases,* reason that *velocity* is a quantity, and *increases* a qualitative relation. It therefore may be concluded that the message is a qualitative statement. Interpretations of this kind are very different from categorical coding, the usual method of analysis in the behavioral sciences in general and CSCL in particular (automatic support for categorical coding is discussed by Rosé et al., 2008; Anjewierden & Gijlers, 2008). Erkens & Janssen (2008) focus on determining the communicative function of messages in online discussions. Their MEPA tool automatically segments messages into one of 29 predetermined categories based on the theory of dialogue acts. Erkens & Janssen state that their automatic procedure can only be used for content that can be indicated by specific marker words, phrases, or actions, which is a limitation of the approach. In *velocity increases* there are no marker words, both words convey meaning. For the automatic analysis of the messages, fitting our research question, a tool which provides more flexibility, in some sense generalizing the idea behind MEPA, is required.

We have used a text analysis tool called tOKo (Anjewierden, 2006). This tool is being used by social scientists to study, for example, online communities (e.g., de Moor & Anjewierden, 2007), and by semantic web researchers to create domain vocabularies and extract semantic relations (e.g., de Boer, van Someren & Wielinga, 2007). Automatic (semantic) text analysis is uncommon in CSCL, so we provide only a global overview of how we applied it to the analysis of the chat messages and omit technical detail where possible. The analysis starts with a corpus that contains all the chats and the objective is to define syntactic patterns in these chats that allow the extraction of the types of contributions we are interested in. For this we must identify the features detailed below.

Domain terms. The domain terms have been selected by sorting all words on frequency and then manually selecting domain terms that occur at least five times. The most frequent word, ignoring stop words, is *ok* (1294), the most frequent domain term is *velocity* (snelheid, 440). Selecting the domain terms took about two hours.

Conditional sentences can be found using discourse markers and they correspond to the categories called *condition* and *consequence* in MEPA. We have identified several syntactic patterns in the corpus which mark a conditional sentence. The most frequent is *als ... dan ...* (if, then), also frequent is *hoe ... hoe ... (*the, the; *the higher the speed, the lower the mass)* and sometimes *... wanneer ...* (when) is used. In the latter case, the condition and the consequence are reversed (*speed increases when mass is increased*).

Qualitative statements. The extraction of qualitative statements consists of three steps. The first step is to enumerate all quantities and all qualitative relations. Next, for each quantity and each qualitative relation we need to find the terms learners use for them. For example, the quantity velocity can appear as *velocity*, *speed*, and *v* (the symbol). Similarly, the qualitative relation *increase* can appear as *goes up*, *higher* and so forth. In our Dutch chats we found seven syntactic patterns for *increase* and eight for *constant*, including the negation *does not change.* Finding these variations is not difficult, the easiest method is to use a quantity as a key word and use a concordance index to inspect the surrounding text. The lower right pane of Figure 1 shows the results for *snelheid*. In the central column the concept snelheid is displayed, and to the left and right the surrounding text, for example, the first line "denk je dat je je snelheid moet veranderen" (do you think you must change your velocity).

We now have a set of syntactic patterns for quantities which we call $quan$ and one for qualitative relations which is called $qual$. The third step is to define patterns for qualitative statements as a whole, they are:

$quan$ ... $qual$ and $qual$ ... $quan$

The first pattern finds phrases in which the quantity appears before the relation and the second pattern finds phrases in which the quantity appears after the relation (*increase speed*). .

In total the selection of the terms and the definition of the patterns took about three man days. Once the patterns are specified, the analysis is automatic. tOKo extracts zero or more clauses from each message. For example, from the utterance *the velocity increases* it extracts:

domain_term(velocity).
domain_term(increases).
qualitative_statement(velocity, increase).

and from *speed becomes larger* it extracts:

domain_term(speed).
qualitative_statement(velocity, increase).

Notice that the qualitative statement extracted is identical in both cases, although the two phrases have not a single word in common. It should be noted that the manual part of the analysis appears to be time consuming, but one should realize that this upfront work greatly reduces the amount of work that otherwise would go into a manual analysis of thousands of chat messages (in this research 18.700). In other words: the investment in identifying syntactic patterns is easily recovered by reducing the investment in the analysis of a large number of chat messages.

We have, of course, omitted several details in the above description. Not every conditional that begins with *if* also contains the corresponding *then,* certainly not in chat text, and it still should count as a conditional sentence. Another, relatively common case when mismatches occur is an overrun of one pattern match into another (Dutch readers will recognize an example in the last line in Figure 1, under the heading Pattern search: *snelheid hoe groter*). The pattern language which has been used in the automatic analysis provides a mechanism to suppress such matches.

The reliability of extraction is difficult to assess, the patterns were derived from the corpus and testing on the same corpus provides no information about reliability for other chat corpora. Some of the terms are very domain related, momentum is an example, and it would probably not make any sense to test the patterns on chats from, say, a thermodynamics domain. To provide some idea about reliability we have manually examined 15% of the chats and computed precision (0.94) and recall (0.88) for the conditional sentences and qualitative statements. Domain terms are found using an algorithmic procedure, this can only affect reliability when a domain term is used out of context (*the speed of your typing is amazing*).

A characterization of the approach we use is that within a limited domain, with a limited vocabulary, it is more or less possible to enumerate the domain terms and use syntactic patterns (Hearst, 1992) to extract meaningful phrases related to the domain. This extraction can be done automatically.

As the result of the analysis outlined, we have for each learner a set of domain statements classified into the three types of contributions. The next question is how to "value" these contributions as they are not equal in their level of cognitive effort to produce them.

Computing the value of domain-related contributions

The level of domain-related contribution, D(*learner*), is computed by assigning a score to each message for any given learner, summing these scores and then dividing by the total number of messages. D(*learner*) is therefore the average domain-oriented content per message. The unit of analysis for this computation (Strijbos et al., 2006) is a single chat message.

The weights used in the scoring function are: +2.0 for a conditional sentence, +1.0 for a qualitative statement, and +0.4 for use of a domain term. These weights have been chosen in such a way that they reflect the cognitive effort of the learner to produce them. The weight -0.5 is given to an agreement. This negative weight penalizes learners who agree more than their peer and can thus be seen as passive, relying on the cognitive efforts of their partner. In all cases, a weight is only assigned once to a single message. If a message contains two domain terms it obtains a score of +0.4 (and not +0.8). The scores for the examples above are +1.4 (*speed increases*) and +3.4 (*if the mass becomes higher, the momentum decreases).* As there is some arbitrariness in the scoring function, we conducted a sensitivity analysis by varying all weights independently in a range of -0.5 to +0.5 from the values defined above and this produced no significant change in the overall outcome: who is A stays A and who is B stays B. This shows that the scoring function is robust, which, of course, does not entail that it is the "correct" function.

Results

The results presented below are based on the data obtained by Saab (2005) on the collision domain as described in the Method section. Saab's original process data, consisting of interactions with the simulation environment and the chats, were first integrated. The chats have been normalized by correcting spelling errors, contractions and other textual noise. Dyads for which at least one of the learners a pre-test or post-test was not available were removed, and so was a single dyad who communicated in a language other than Dutch. The process data from the 66 dyads that remained contained 18,007 chat messages. Data with respect to the chat communication, particularly the number and nature of chat messages, is displayed in Table 1.

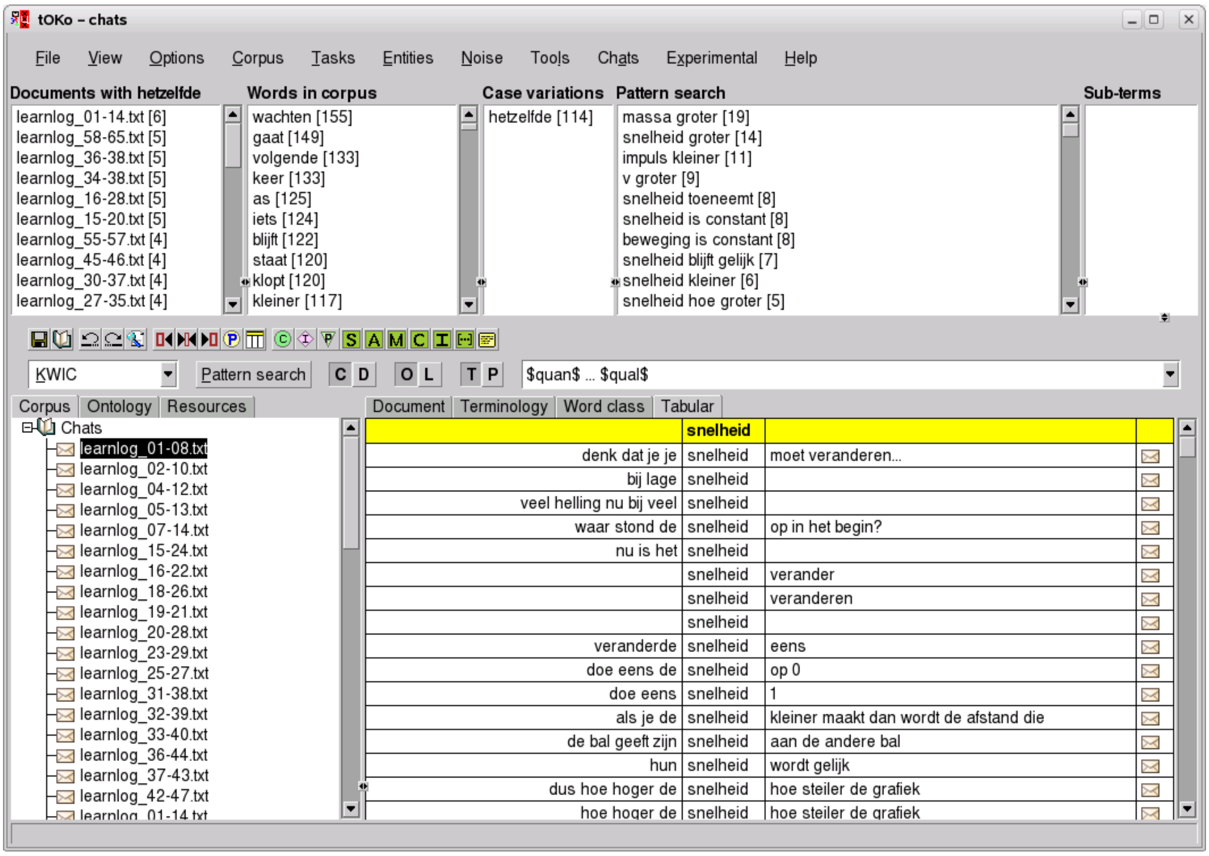

Figure 1. The application of the tOKo text analysis tool on the collision chat corpus.

Table 1: Data chat messages

	Group			
	A (n = 66)		B (n = 66)	
	M	*SD*	*M*	*SD*
Number of messages expressing				
Agreement	25.83	13.70	33.95	16.71
Domain terms	15.08	9.19	12.08	8.53
Conditional sentences	1.82	1.65	0.94	1.38
Qualitative statements	4.38	3.10	2.64	2.64
Total number of chat messages	138.03	58.72	134.20	56.84
Chat score per message	0.10	0.10	0.02	0.08

The data regarding chat messages displayed in Table 1 were analyzed by means of two-sided Wilcoxon signed rank tests. With regard to Agreement it was observed that B's express agreement more frequently compared to A's (z = -4.28, p < .001). On the other hand, compared to B's, A's mentioned more domain terms in general (z = -2.73, p < .01), made more conditional sentences (z = -4.00, p < .001), and more qualitative statements (z = -4.26, p < .001). The number of chat messages did not differ between A's and B's (z = -0.97, p = .33). By definition, the chat scores differed in favor of the A's (z = -7.06, p < .001).

In Table 2 the results of the two knowledge tests (definitional knowledge and intuitive knowledge (what-if)) are displayed. Group A contains the learners with the highest domain-related chat score within a dyad, and group B contains the lowest scoring partners in a dyad.

Table 2: Results knowledge tests

	Group			
	A (n = 66)		B (n = 66)	
Category	*M*	*SD*	*M*	*SD*
Definitional knowledge				
Pre-test	6.39	2.26	5.98	2.35
Post-test	8.09	2.29	7.36	2.81
Gain from Pre to Post	1.70	3.06	1.38	3.36
Intuitive knowledge				
Pre-test	4.76	2.12	4.97	1.95
Post-test	7.55	2.29	6.91	2.33
Gain from Pre to Post	2.79	2.25	1.94	2.41

In order to gain more insight in knowledge gains within and between Group A and Group B, the data displayed in Table 2 were analyzed by means of paired samples T-tests. Sidak's correction for multiple comparisons was applied to control for chance capitalization.

With regard to *definitional knowledge*, within Group A a significant knowledge gain was observed, that is their post-test scores were significantly higher than their pre-test scores (t = -4.51, p < .001). The same was true for the knowledge gain within Group B (t = -3.33, p < .01). Comparisons between Group A and B showed that their pre-test scores were equal (t = 1.02, p = .31) and so are their post-test scores (t = 1.84, p = .07) and definitional knowledge gain (t =.59, p = .56).

Regarding *intuitive knowledge*, the knowledge gain within Group A was significant (t = -9.01, p < .001) and so was the gain among B's (t = -6.54, p < .001). Furthermore, comparison between A's and B's showed that A's intuitive knowledge gains were greater than those of B's (t = 2.35, p < .05). A's and B's did not differ from each other with regard to pre-test score (t = -0.58, p = .57), post-test score (t = 1.94, p = .06).

What students talk about can influence what they learn, and conversely, what they learn (or already know) can influence what they talk about. In order to investigate how A and B's knowledge, learning, and communication relate to each other, Pearson's product-moment correlations between A's and B's have been calculated with regard to knowledge measures, chat messages, and chat scores, (see Table 3).

Table 3: Product-moment correlations between group A (rows) and B (columns)

		Group B											
		Knowledge measures						Chat communication					
Group A		1	2	3	4	5	6	7	8	9	10	11	12
Knowledge measures	1 Pre-test definitional						-.28*						
	2 Pre-test intuitive												
	3 Post-test definitional												
	4 Post-test intuitive			.29*	.33**		.26*						
	5 Gain definitional				.27*								
	6 Gain intuitive				.41**		.29*						
Chat communic.	7 Agreement							.62**	.25*			.41**	-.30*
	8 Domain terms	-.27*						.36**	.48**	.33**	.48**		
	9 Conditional sent.	-.26*								.32**	.29*	-.29*	.28*
	10 Qualitative statem.	-.27*							.34**	.45**	.50**		.31*
	11 Number messages							.36**				.41**	
	12 Chat score/message							-.35**		.40**		-.36**	.48**

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

The *top-left quadrant* of Table 3 displays the correlations between A's and B's knowledge measures. It can be observed that particularly A and B's intuitive knowledge gains (6) and their intuitive knowledge scores on the post-test (4) are related to each other.

The *top-right quadrant* is empty, indicating that there are no correlations between A's knowledge measures (1-6) and B's communication (7-12).

The *bottom-left quadrant* shows that there are some correlations between B's knowledge measures (1-6) and A's communication (7-12): B's prior definitional knowledge (1) is slightly and inversely related to A's frequency of expressing domain terms (8), conditional sentences (9), and qualitative statements (10).

The quadrant at the *bottom-right* of the table, displays correlations between A's and B's communication. The correlations on the (shaded) diagonal suggest that students within dyads "mirror" each other. There is not only a moderate positive correlation between the number of chat messages uttered by A's and B's (11), but also the nature of the messages (7-10) is found to correlate positively. For example, if one peer expresses agreement (7) often, the other peer is likely to do so as well (r = .62); if one peer frequently makes qualitative statements (10), the other peer is likely to frequently make qualitative statements too (r = .50), and so on.

Conclusion

In this study it was found that within dyads, the students who post more domain-related messages often gain more intuitive knowledge than their partners. Nonetheless, the data also showed that gains in intuitive knowledge of A's and B's are positively correlated. Furthermore, A's use domain terms, conditional sentences, and qualitative statements more frequently, in particular when their partners' prior definitional knowledge was rather weak. These partners in turn often express more statements reflecting agreement ("yes", "ok", and so on). They seem to leave the externalization of knowledge and ideas to their partners, mostly replying by expressing agreement only. This is also called cumulative talk (e.g., Mercer, 1996). In other studies, the acquisition of intuitive knowledge has been found to be fostered by processes of drawing conclusions, interpretation and sense-making (Gijlers & de Jong, submitted; Reid, Zhang, & Chen, 2003; Zhang, Chen, Sun, & Reid, 2004). Students actively attempting to make domain-related contributions to the communication, instead of mainly agreeing with statements of their partner, are possibly more likely to actively engage in these processes and to externalize them, which might explain their higher gains with respect to intuitive knowledge.

The correlation analysis also indicated that the lower the initial definitional knowledge of B's, the more A's posted domain-related messages, which suggest A's explained the domain to their partners. As stated in the introduction section, providing elaborate explanations is often more beneficial than receiving explanations (e.g., Webb, 1989), because students who are providing elaborate explanations are actively engaged in externalization processes. With regard to communication, it was observed that students within dyads seem to "mirror" each other: if one peer posts more domain-related messages, the other peer is also more likely to post domain-related messages (see Table 3). The number of messages posted by A's and B's is positively correlated, the chat scores, which give an indication of domain-relatedness of the chat, of A's and B's were also positively correlated. Moreover, the positive correlations between A's and B's also extend to the level of types of chat messages (e.g., conditional sentences, qualitative statements): if one peer posts more qualitative statements, the other peer is also more likely to post qualitative statements, and so on.

As for future research, the analysis used in this paper cannot answer the question how these different types of messages are distributed over time and how messages of A's and B's relate to each other. This analysis can shed light on how the interaction between partners in a dyad develops over time. For example, it is interesting to investigate if the number of relatively high-level contributions increases or decreases during the interaction. From this it could be inferred how long a fruitful collaborative learning session should last. If the number of high-level contributions starts to decrease, one could argue that continuing the session will, in general, not contribute much more to better learning results. Another question is if there are differences in learning outcomes for balanced and unbalanced dyads. A balanced dyad is a dyad in which the contribution of each partner is at approximately the same (higher) level, for an unbalanced dyad the number of high-level contributions of one partner substantially exceeds the contributions of the other partner. One of the assumptions behind collaborative learning is that pairing high-level contributors with low-level contributors will benefit both in terms of learning results, but maybe the low-level contributor benefits more. Analyzing the learning results of balanced and unbalanced dyads could confirm or reject this assumption.

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Online and face-to-face discussions in the classroom: A study on the experiences of 'active' and 'silent' students

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Abstract: Even though the advantages of online discussions over face-to-face discussion formats has been extensively reported and investigated, the blending of online discussion tools in co-located classroom settings has been considered with far less intensity. In this paper, we report on secondary school students' experiences and preferences concerning two different discussion formats in co-located classroom settings, namely face-to-face (F2F) and synchronous, computer-mediated communication (CMC). In addition, we also differentiate between students that are known to be active participants in F2F classroom discussions and those who usually remain silent. The findings highlight several advantages of CMC over F2F discussions in co-located settings and show that different students ('active' and 'silent') experience F2F and computer-mediated communication differently.

Introduction

Many theories of learning have recognized the importance of peer dialogue in learning and teaching (e.g., Rogoff, 1998; Wegerif, 2007). However, whereas passive observation of peer dialogue may be beneficial in some cases, several studies have shown that it is the *active* participation in processes such as constructing explanations , providing help and engaging in dialectical argumentation that seem to be responsible for the more substantive learning gains (e.g., Asterhan & Schwarz, 2008; Chi, Roy, & Hausmann, 2008; Webb, Troper, & Fall, 1995). When implemented in authentic classrooms, discussions usually take on a format of teacher-led classroom discussions or small group peer discussions. Both formats have significant shortcomings which may reduce the effect of the advantages of un-moderated peer dialogue (e.g., superficial student involvement, unequal participation rates and extensive teacher interference, and disorganization, peer dominance and lack of coherence, respectively).

Computer-mediated discussion boards have been suggested to be able to overcome several of these shortcomings: First of all, and as has been discussed extensively (e.g., Kiesler, Siegel & McGuire, 1984), a great deal of the non-verbal cues that are present in face-to-face (F2F) communication are lacking in distributed CMC. Since these non-verbal cues are, among others, used to assess social status, computer-mediated communication has the potential of being more democratic (Herring, 2004). Moreover, the increased anonymity of on-line communication is thought to cause people to become less inhibited and to self-disclose more frequently (Suler, 2004). This decrease of authority, social status and inhibitions in combination with the lack of need to compete for speaking rights may thus promote free expression of individual standpoints and increased and equalitarian participation by all discussants. In addition, the textual medium of communication, the ability to re-read and re-vise contributions, and the fact that in a-synchronous CMC there is an increase in the amount of time available to think and consider one's response before posting it, are all thought to encourage reflection (Guiller, Durndell, & Ross, 2008; Kim, Anderson, Nguyen-Yahiel, & Archodidou, 2007). Others have argued that even though F2F discussion modes may be particularly suitable for the creation of new ideas and for brainstorming, a-synchronous CMC promote explicitness in communication and increase the rate of substantive and reasoned contributions (Kim et al, 2007; Newman, Webb, & Cochrane, 1995). This, in turn, may have been the result of increased opportunities for reflection and the need to be more explicit in light of the lack of non-verbal cues.

However, most of the studies that compare F2F with on-line discussion formats have focused on text-based discussion environments that occur in a-synchronous, distributed, distant communication modes (such as in the framework of e-courses, homework assignments, and after-school social communication). In this study we will focus on the blending of *synchronous*, text-based discussion tools within *co-located* classroom settings, a topic that has, thus far, rarely been the focus of research (Cuban, 2002). The use of on-line communication in co-located settings may combine some of the advantages of online communication, without some of the potentially problematic aspects of distant, anonymous communication formats in educational settings: On the one hand, its textual nature, lack of non-verbal cues, persistence of contributions and simultaneous nature may encourage reflection, explicitness, interactivity and participation. On the other, student discussants share a physical space, they personally know their discussion partners and the teacher is physically present. This could avoid some of the negative sides of distant, anonymous CMC in secondary education settings, such as teacher difficulty to verify whether a certain task is actually completed by the student or not, instances of flaming and other social disturbances, and lack of accountability for communication content. Another difference with the above-mentioned studies and the present one concerns the fact that the former have mainly focused on objective rates and aspects of communication and have not explored how these different communication formats are perceived and experienced by the students using them.

In the present study, we then seek to investigate students' preferences of and experiences with two different discussion formats (F2F and CMC) in co-located classroom settings. We focus on several discussion aspects, such as participation, interactivity, learning and classroom management. The student population should not be considered as homogeneous in their behavior and in their preferences for different communication modes (see also Caspi, Chajut, Saporta, & Beyth-Marom, 2006, Eisenmann & Even, in press). We therefore differentiate between students that are known to be active participants in F2F classroom discussions ('active' students) and those who do not participate frequently ('silent' students). We expect that they differ in the extent to which they welcome the introduction of these new technologies in the classroom: Compared to active students, silent students are expected to show a stronger preference for the online format. We also expect this difference to be strongest for discussion characteristics that involve rate of participation, rate of peer interaction and motivation.

Method

Participants

Twenty-three 9th grade students and ten 11th grade students from a secondary school in the Jerusalem metropolitan area participated in this study. All students filled out a questionnaire on their experience of face-to-face and on-line classroom discussions (see Tools section). In addition, four 9th graders (two 'active' and two 'silent' classroom discussion participants) participated in short, individual structured interviews on this experience. They were selected based on the teacher's evaluations of the most active and most silent students in face-to-face classroom discussions.

Tools and Procedure

All students had participated in at least two classroom activities in three different subjects (civic education, biblical studies and history) that blended traditional teaching activities with online discussions. The discussions were conducted within the Digalo environment (e.g., Schwarz & de Groot, 2008) which enables synchronous, textual talk through mediation of geometrical shapes (diagrams) that represent different dialogical moves (such as, argument, explanation, claim, and so forth).

A questionnaire was developed in which students were asked to indicate their personal experiences with on-line Digalo and face-to-face classroom discussions in a comparative way. It included twelve statements that described different aspects of students' personal experience in discussions. The items assessed aspects of interaction ("Students reacted to my contributions", "I reacted to the other students' contributions"), participation ("I participated in the discussion", "I had the opportunity to express myself"), the learning experience ("I felt that I learned new things on the subject", "The discussion caused me to think about the subject",), clarity ("I understood the discussion topic", "I managed to follow the discussion development"), motivation ("I was interested in the topic", "I enjoyed the discussion"), and classroom management ("There were a lot of classroom disturbances", "Students engaged in off-topic behavior"). For each item, students were asked to indicate whether the statement characterized themselves more in Digalo discussions, more in face-to-face classroom discussions, or equally well. Values ranged from 1 (much more in Digalo discussions) to 5 (much more in classroom discussions). In addition, students were asked to self-report on their frequency of participation in face-to-face classroom discussion, ranging from 1 (almost never) to 4 (a lot). Finally, the questionnaire also contained an open-ended question which asked of students to indicate whether they would like to have Digalo discussions in their classroom activities more frequently and why.

The interview was developed in parallel to the questionnaire and its aim was to expand the understanding of the findings from the questionnaires analysis (Johnson & Onwuegbuzie, 2004). The interview was conducted by a previously unknown person to the students and started with a request to describe classroom discussions and electronic discussions. During these descriptions the interviewer prompted for further explanations and examples. Following, students were asked why they believe the electronic tool was developed and whether they expect that its usage will impact the discussion practices in the classroom.

Results

The comparison between the different discussion styles (F2F and CMC) proved to be quite natural for the students and they were very cooperative. Student responses to the twelve forced-choice items were recoded by a linear transformation, such that a preference for Digalo discussions was indicated by positive response values, a preference for classroom discussion by negative response values and a lack of preference by null values. Values for the two classroom management items were reversed, such that more disturbance or more off-task behavior in one discussion format indicates a preference for the opposite discussion format. Mean preference scores were calculated for the whole sample and are reported in Table 1. Positive values indicate a mean preference for on-line discussions and negative values a mean preference for F2F classroom discussions (range from -2 to 2). All statistical analyses were conducted with two-tailed t-tests.

Table 1: Mean number (and SD) of pupils' self-reported preference scores for face-to-face or on-line discussions on selected discussion characteristics (N=33)

Discussion characteristics	*M*	*SD*	
Reactions of others to self	.42	1.30	p = .070
Reactions of self to others	.49	1.35	*
Self-expression	.48	1.30	*
Participation	.24	1.20	
Interest	-.06	1.12	
Enjoyment	.00	1.20	
Caused to think	.19	.10	
Learned new things	-.09	.88	
Understand topic	.80	1.10	
Follow discussion	-.33	1.24	
Classroom disturbances	.97	1.04	****
Off-task behavior	.85	1.15	****

* p < .05, p < .005, ****

The mean preference scores in Table 1 show a general trend for preference of online Digalo discussion over face-to-face classroom discussions for 8 out of the 12 different discussion characteristics tested. These preferences in favor of online Digalo discussion formats were significantly larger than chance for measures of classroom management (classroom disturbance and off-task behavior), interactivity and self-expression .Indeed, in all interviews differences related to classroom management were mentioned. The students distinguished between the different discussion formats: while one is quiet ("in Digalo it's quite" or "the lessons were conducted quietly because the discussion was going in writing"), the other is noisy ("there is much more noise"). In addition, the interviewees mentioned that in a regular lesson the teacher is occupied with discipline problems, while in Digalo-lessons the teacher is more available for other issues:

> "in Digalo[-lesson] the teacher walks between the students and checks if everything is OK… and if there are questions we can ask him. In regular lesson [F2F discussion] the teacher is busy with discipline problems…" (*interviewee #3)*

The difference that students experienced with regards to the opportunities to interact with fellow peers was also recurrently mentioned in the interviews, as is shown in the following excerpts :

> "I think it would have been easier [in Digalo-discussion] … to understand other side's opinion, what they think… would have been easier to change your opinion or understand another opinion" (*interviewee #4*)
> "… and in Digalo it is quiet and you can see, you sit in front of the computer by yourself, see what people write… and can refer to each thing separately and in your own pace… next to the computer I found it easier to express myself" (*interviewee #3*).

Following this exploration, we then turned to a comparison of discussion format preferences as a function of students' self-definition as high or as low frequency participants in face-to-face classroom discussions. Low participants were operationally defined as those students that indicated that they "almost never" or "every now and then" participated in classroom discussions (N = 15), whereas high participants indicated that they did so "often" or "a lot" (N = 18). Mean preference scores for these two groups are presented in Table 2.

First of all, the data in Table 2 show that, overall, discussion format preferences were consistent with being high or low frequency participants in face-to-face classroom discussions on most discussion aspects: On all but the classroom management aspects and understand topic. The high frequency participants' scores indicate an overall preference for face-to-face classroom discussions (10 out of 12 different discussion characteristics tested). These preferences reached statistical significance on the following aspects: rate of participation, the ability to follow the discussion, the ability to learn new things and the number of classroom disturbances. In the interviews the high-frequency students did not reveal any clear preferences for one format over the other.

Table 2: Mean number (and SD) of pupils' responses, by low frequency participants and high frequency participants in F2F classroom discussions

Discussion characteristics	*Low F2F participants (n=15)*		*High F2F participants (n=18)*		
	M	*SD*	*M*	*SD*	
Reactions of others to self	1.20****	.77	-.22	1.31	*t* (33) = 3.87***
Reactions of self to others	1.40****	.74	-.28	1.27	*t* (33) = 4.50****
Self-expression	1.53****	.52	-.39	1.09	*t* (33) = 6.63****
Participation	1.77****	.49	-.67**	.77	*t* (33) = 9.08****
Interest	.40	1.06	-.44	1.04	*t* (33) = 2.31*
Enjoyment	.47	1.19	-.39	1.09	*t* (33) = 2.15*
Understand topic	.07	1.03	-.61	1.09	*t* (33) = 1.82
Follow discussion	.13	1.19	-.72*	1.18	*t* (33) = 2.07*
Caused to think	.73**	.79	-.28	.96	*t* (33) = 3.25***
Learned new things	.40	.74	-.50*	.79	*t* (33) = 3.37***
Classroom disturbances	1.33****	.72	.67*	1.19	*t* (33) = 1.90
Off-task behavior	1.27****	.80	.50	1.29	*t* (33) = 1.99

* p < .05, ** p < 0.01, *** p < .005, **** p < .001

The low frequency participants, on the other hand, consistently tended to indicate preferences for the online discussion format on all test items. This preference was strongest and statically significant for the following dimensions: They reported that they interacted more with their peers, that they participated more and felt that they could express themselves more, and that the group as a whole suffered from far less classroom disturbances and off-task behavior. It seems that those students had started to develop new discussion practices, which they find it interesting and efficient for their learning. As one of the student mentioned:

> "In Digalo most of the students are busy with writing, [it gives] opportunity to each one to express himself more than he does usually… from Digalo I learned more than discussion of the same topic in the class… in the class I don't participate so much" *(interview #2*)

At a later point in the interview he furthermore added that in his opinion the written discussion is in "*higher language*" due to the need to be more precise and different communication norms.

Statistical comparisons between high and low frequency participants' scores proved that the above-described differences in preference patterns between these two types of students were significant for nine of the twelve discussion characteristics assessed in the questionnaire. Interestingly, even though 'active' students indicated a weak overall personal preference for the F2F format, they did voluntarily acknowledge and appreciate the advantages of CMC discussion for their fellow 'silent' classmates:

> "Specifically, for me there was no difference, but I know about other students who found it easier to express themselves in writing rather than verbally… for me it was about the same… during discussion in class there are much less students participating… Digalo really helps, for me as well as for other students, to express themselves, it teaches a lot" (*interviewee #1*)
>
> "For me it is about the same because I do participate, but [for] students who don't participate it helps them to better understand the material, to understand what other students say" (*interviewee #4)*

This was further supported by the students' responses to the open-ended question in the questionnaire, in which many mentioned this particular advantage voluntarily (without being prompted).

Discussion

The blending of online discussion tools in co-located classroom settings can alter discussion practices in a classroom. Since turn-taking is not required and many non-verbal cues are not conveyed, it may promote more democratic student participation, the free expression of ideas and increase student peer interaction. In addition, students also reported that they experienced less classroom interruptions and disturbances in this format. On the other hand, it avoids some of the more undesired phenomena associated with distant, anonymous CMC, such as social and learning disturbances. Our findings also showed that different students (active and silent) experience F2F and computer-mediated communication differently. In CMC environments, students that are usually quiet in F2F classroom discussions seemed to have begun to develop discussion practices as active participants and readily identified the advantages of online peer discussions. The more "active" students, on the other hand, had well-founded discussion practices and therefore received the new communication format with reservations. However, they did acknowledge the advantages for their "silent" fellow classmates. To further examine these first findings on different communication media within co-located classrooms, direct observations of student behavior during on-line and F2F discussions will have to complete the picture. A particular interesting venue for future research concerns the questions whether the development of these new practices will carry over to F2F classroom discussion activities. For example, will the participation in a sequence of online discussions change the silent students' behavior in F2F discussions?

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Conceptual and procedural knowledge construction in computer supported collaborative learning

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Abstract: This paper focuses on learners' knowledge construction in computer supported collaborative learning. It investigates how far individual knowledge (prior knowledge), collaborative knowledge (the quality of collaborative knowledge construction), and instructional support may contribute to the outcomes of learners' knowledge construction. It analyzes predictors for learners' learning outcomes with respect to procedural knowledge (successful application of rules for case-solving) and conceptual knowledge (cued answer of theory concepts) under consideration of learners' knowledge about theory definitions. To find answers to this issue, results of two studies are presented. They show that predicting factors for learners' construction of conceptual knowledge lie mainly in the individual while procedural knowledge benefits of collaborative knowledge construction.

Knowledge construction in computer supported collaborative learning

Computer supported collaborative learning environments can provide learning experiences which go far further than the pure acquisition of facts. Some focus, for example, on the *transfer* of knowledge (e.g. Renkl, Mandl & Gruber, 1996), some on learners' knowledge about *argumentation* (e.g. Schwarz, Neumann, Gil & Ilya, 2003), some on their *problem-solving* skills (e.g. Saljö, Eklund & Mäkitalo, 2006) or particular domain-specific *strategies* (e.g. Fischer, Mandl, Kollar & Haake, 2007). Research in these fields analyzes often how learners improve their knowledge and skills while learning in these environments and focuses thereby on aspects that the environment aims to facilitate (e.g. argumentation, problem-solving skills, and strategies). Questions about how the individuals and the collaboration contribute to the group's and to the learners' knowledge construction remain often unanswered. Yet, to examine the potentials of computer supported collaborative learning for collaborative knowledge construction, one has to look deeper into the collaboration scenario with respect to individual and collaborative aspects that may contribute to learners knowledge construction. Schwarz et al. (2003), e.g., found in a study about the construction of collective and individual knowledge in argumentation that there were significant differences between individual and collaborative arguments and that individual arguments improved after collaboration.

De Jong and Fergusson-Hessler (1996) present a framework to distinguish different kinds of knowledge. They present four different types of knowledge and define *situational knowledge* as "knowledge about situations as they typically appear in a particular domain" (p.106), *conceptual knowledge* as "static knowledge about facts, concepts and principles that apply within a domain" (p. 107), *procedural knowledge* as "actions or manipulations that are valid within a domain" (p.107), and *strategic knowledge* which "helps students organize their problem-solving process by directing which stages they should go through to reach a solution" (p.109). Learners may work with all of these four knowledge types in the context of a learning environment, but there may be specific gains in particular aspects, e.g. strategic and procedural knowledge in problem-solving environments (Rummel & Spada, 2006). Besides that, de Jong and Fergusson-Hessler (1996) distinguish five different qualities of knowledge with respect to each type. Combining all the types and qualities of knowledge creates a matrix with 20 dimensions of knowledge. One of these dimensions is the *level of conceptual knowledge*, which is an indicator for the quality of learners' conceptual knowledge. This level may range from low (surface knowledge, e.g. symbols, formulae, definitions) to high, which means deeper knowledge and comprises concepts and relations.

Research Questions

This paper investigates two different types of knowledge during collaboration. It analyzes how they are involved in learners' collaborative and individual knowledge construction and how much of the learning outcomes they predict. The particular research questions are:

1. *What are predictors for the quality of collaborative knowledge construction?*
2. *What are predictors for learners' construction of procedural knowledge?*
3. *What are predictors for learners' construction of conceptual knowledge?*

Method

To answer the research question, two empirical studies were conducted in the laboratory of Ludwig Maximilian University. 159 undergraduate students of social sciences took part in the first study and 171 freshmen of educational sciences in the second.

Experimental paradigm and Design

The experiment comprised an individual and a collaborative learning unit (see 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, a short-answer test, and a multiple-choice-test. 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. After the collaborative learning unit, learners' knowledge was assessed on an individual basis by asking them to solve a case and to complete a short-answer test. These tests reflect the assessment of different types of knowledge. In particular, the cases focused on procedural knowledge to disclose, how far learners could apply specific rules that are necessary to analyze attribution patterns, the multiple choice test analyzed theory definitions and gave therefore insights in learners' conceptual knowledge on a low level, and the short answer test asked learners to describe theory concepts on their own, which can disclose conceptual knowledge on a higher level. Due to the relatively short experimental session, situational knowledge and strategic knowledge could be not assessed.

During collaboration, groups of three learners worked in one of four conditions of a 2x2-factorial design. The support measures of both studies were either content-specific or collaboration-specific. In study 1, the factor content-specific support compared a content-scheme vs. no support; in study 2 it compared the content-scheme vs. an enhanced content-scheme. This means that all learners of study 2 worked with the content-scheme that was applied in study 1. The factor of collaboration-specific support compared a collaboration script vs. no support in study 1 and strong resource interdependence vs. light resource interdependence in study 2. The issue of the particular role of support has minor importance for this analysis. More details about the support measures and their influences can be found in former publications, e.g. Ertl, Kopp and Mandl (2005) for study 1 and Ertl and Mandl (2006) for study 2.

Data Sources

Several data sources were included to assess the individual's prior knowledge, the quality of collaborative knowledge construction, and the individual's learning outcome.

Prior knowledge: conceptual (definitions) was measured by a multiple-choice test, which consisted of 12 items. Learners had to find the right answer out of four choices. The reliability of this test was sufficient in both studies (Cronbach's $\alpha > .64$; 1).

Prior knowledge: conceptual (concepts). Conceptual knowledge was measured by a short-answer test for describing theory concepts. This test consisted of 8 items. The reliability of this test was sufficient in both studies (Cronbach's $\alpha > .69$).

Prior knowledge: procedural. Concerning procedural prior knowledge, learners worked on a case individually. This case solution was analyzed with respect to the application of theory concepts on case information. Items used correctly for the individual case solution were summed up as a score. For ensuring inter-rater reliability of data, two evaluators marked analysis 10%. The consistency between these evaluations was high for both studies ($\kappa_w > .91$).

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 theory concepts, which had to be applied correctly on 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 in both studies ($r > .87$; 2).

Learning outcomes: conceptual (concepts). Conceptual knowledge in the post-test was measured individually by a short-answer test for describing 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 for both studies (Cronbach's $\alpha >$ .62).

Learning outcomes: procedural. For determining learning outcome (procedural 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 for both studies ($\kappa_w > .90$).

Control variable. Students' age was used as a control variable.

Data analysis. Linear regressions (enter method) were computed to find predictors for the quality of collaborative knowledge construction and individual learning outcomes. The analyses were calculated on the individual's level (except the measures with the quality of collaborative knowledge construction as outcome variable which were calculated on the group level). For testing group effects, all data was re-calculated with Hierarchical Linear Models (HLM). Yet, differences between both methods of analysis were marginal because of the small group size of triads and the short time of collaboration.

Results

The following section presents results of both studies with respect to the three research questions.

Research question 1

Research question 1 asked for indicators for the quality of collaborative knowledge construction. Regarding this measure, there are differences between study 1 and study 2 (see table 1). In study 1, 47% of the variance could be resolved. In the context of the three different measures for prior knowledge, only the content scheme proved to be a significant predictor. However, omitting the variable of conceptual knowledge (definitions) would result in a small impact of prior knowledge (see Ertl, Kopp & Mandl, 2005). With respect to study 2, 34% of the variance could be resolved. In the context of the three different measures for prior knowledge, only the conceptual knowledge (definitions) proved to be a significant predictor. Furthermore, learners' age had a negative influence.

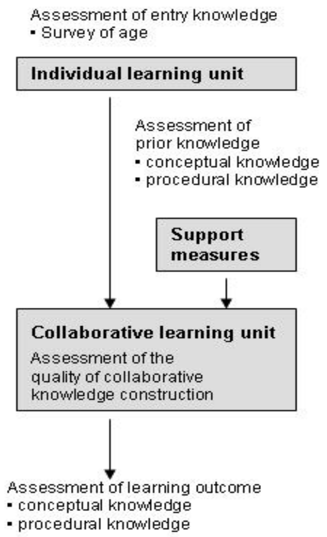

Figure 1: Experimental paradigm of the studies

Table 1: Predictors for the quality of collaborative knowledge construction by prior knowledge, support and age. Predictors with standardized β-weights and significance level.

	Quality of collaborative knowledge construction			
	Study 1		Study 2	
	β	*p*	β	*p*
Age	—	*n.s.*	-.31	< .05
Prior knowledge (procedural)	—	*n.s.*	—	*n.s.*
Prior kn. (conceptual, def.)	—	*n.s.*	.46	< .01
Prior kn. (conceptual, concepts)	—	*n.s.*	—	*n.s.*
Collaboration specific	—	*n.s.*	—	*n.s.*
Content specific	.62	< .001	—	*n.s.*
R^2	.48		.42	
Adjust. R^2	.47		.34	

Research question 2

Looking at individual learning outcomes (procedural knowledge) the results of study 1 and 2 have some similarities. With respect to study 1, 42% of the variance was predictable. Thereby, the quality of collaborative knowledge construction and conceptual knowledge (concepts) had nearly the same impact. Procedural knowledge had a much smaller impact. Furthermore, there are indicators for a detrimental impact of students' age. With respect to study 2, 31% of the variance was predictable. Thereby, the quality of collaborative knowledge construction, conceptual knowledge (definitions) and procedural knowledge had nearly the same impact. The content-specific support had only a smaller impact.

Research question 3

Regarding individual learning outcome (conceptual knowledge, concepts), both studies show similar results. In study 1, 65% of the variance could be resolved. Thereby, only the three different measures of prior knowledge were influential. Most effect had the conceptual knowledge (concepts), followed by the conceptual knowledge (definitions) and procedural knowledge. The other variables were not significant. Regarding study 2, 66% of the variance could be resolved. Thereby, the conceptual knowledge (concepts) had the highest impact. Procedural knowledge and content-specific support had only a small influence. Furthermore, learners' age had a slightly detrimental impact.

Table 2: Predictors for the learning outcome (procedural knowledge and conceptual knowledge, concepts) by prior knowledge, quality of collaborative knowledge construction, support and age. Predictors with standardized β-weights and significance level.

	Learning outcome (procedural knowledge)				**Learning outcome (conceptual knowledge, concepts)**			
	Study 1		Study 2		Study 1		Study 2	
	β	*p*	β	*p*	β	*p*	β	*p*
Age	-.13	= .07	—	*n.s.*	—	*n.s.*	-.12	< .05
Prior knowledge (procedural)	.18	< .05	.21	< .01	.16	< .01	.12	< .05
Prior knowledge (conc., def.)	.34	< .001	.28	< .01	.28	< .001	—	*n.s.*
Prior knowledge (conc., conc.)	—	*n.s.*	—	*n.s.*	.47	< .001	.68	< .001
Quality of collaborative knowledge construction	.33	< .001	.25	< .001	—	*n.s.*	—	*n.s.*
Collaboration specific	—	*n.s.*	—	*n.s.*	—	*n.s.*	—	*n.s.*
Content specific	—	*n.s.*	.14	< .05	—	*n.s.*	.11	< .05
R^2	.44		.34		.66		.67	
Adjust. R^2	.42		.31		.65		.66	

Discussion

Results show that there are different influencing factors for the quality of collaboration and for individual learning outcomes. For the quality of collaborative knowledge construction, these factors range from the conceptual support in study 1 to the individual's prior knowledge in study 2. Keeping in mind, that all learners of study 2 worked with the conceptual support of study one (see Ertl, Kopp & Mandl, 2008; Ertl & Mandl, 2006), one can assume that the individual's prior knowledge has a high influence on collaborative settings, but it may be overridden by methods of instructional support.

Looking at individual learning outcomes, there are differences between the different types of the conceptual and the procedural knowledge. Regarding procedural knowledge, results show that the quality of collaborative knowledge construction had a strong impact on the learning outcomes—even stronger than the procedural prior knowledge. Similar results are described by Schwarz et al. (2003), who reported in their study about individual and collaborative aspects of argumentation that learners' individual arguments improved after collaboration. This finding indicates that the multiple perspectives incorporated by collaborative learning serve as a particular stimulus for a high quality of learning (see Ertl, Winkler & Mandl, 2007). It also supports Cohen (1994), who argues that collaboration has a value per se and creates something more than just the addition of collaboration partners' skills (Hertz-Lazarowitz, Kirkus & Miller, 1992). Yet, another strong impact on procedural knowledge was learners' knowledge about definitions. This means that learners need a sound theoretical base to use with their procedural knowledge.

The results are different regarding conceptual knowledge. The main predictor for conceptual knowledge was learners' prior knowledge of concepts. Other kind of prior knowledge had much smaller weights and the quality of collaborative knowledge construction didn't prove to have a significant influence. That may be specific to case- and problem solving scenarios, because they focus learners on finding a joint solution (applying the theory definitions and the procedures) rather than on the mutual elaboration of theory concepts, which may, e.g. take place during peer-teaching.

Furthermore, a detrimental effect was found for students' age which indicates that younger students scored better. This effect should not be interpreted in the context of age and cognitive abilities, but rather in the context of study biographies and experiences. One could speculate that the more experienced students used less mental effort for the learning session because it was not graded.

Limitations of the study. There are some limitations for interpreting this study. For experimental purposes, it mainly focused on procedural and conceptual knowledge in case-based learning. For a better understanding of how knowledge develops in collaboration, further types of knowledge have to be investigated in more different scenarios. Furthermore, to have a better insight in the contribution of the individual and the group, a control group with only individuals should have served as baseline.

Summary and Outlook. The significance of this paper relates to several aspects:

(a) There are different predictors for the outcomes of the group and the outcomes of the individual.
(b) Collaboration in a particular learning scenario, here case-based learning, can have an impact on a specific kind of knowledge (here procedural knowledge), but not on all kinds of knowledge.
(c) Technological and instructional factors play often a minor role in comparison with individual factors like the learners' prior knowledge.
(d) Learners' outcomes are not only influenced by their individual prerequisites but can be improved by the quality of collaboration and instructional design.

This study is a first analysis of predictors for learners' construction of different types of knowledge during collaboration. At the current stage, there are only regressions to support the analysis. A further step should also analyze knowledge gains to get an impression *to which extent* this knowledge develops during collaboration. More sophisticated methods of analysis like path analysis or mediator analysis may give further insights in the issue raised by this paper.

Endnotes

(1) Conceptual knowledge (definitions) was assessed in study 1 before and after collaboration. The results showed that learners were able to identify the right definitions to a major extent before collaboration, which left little space for improvement. Therefore, it was omitted in study 2 as measure after collaboration and can therefore not serve as outcome variable.
(2) It would have been more appropriate to present a κw also for the quality of collaborative knowledge construction. However, only a r coefficient can be presented because the value range in this measure exceeded features of the analysis software.

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Exploring the Effectiveness of an Idea-centered Design to Foster a Computer-Supported Knowledge Building Environment

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Abstract: This paper compares the effectiveness of two multimedia environments—Blackboard Learning System™ and Knowledge Forum™—in terms of their underlying design approaches to support collaborative learning and knowledge work. The two design approaches are (1) a conventional theme-based approach, i.e., to center group collaboration and meaning interaction around themes, and (2) an idea-centered approach, i.e., to center group collaboration and meaning interaction around sustained idea exchange and improvement. Findings suggest that an idea-centered design approach seems more likely to construct an environment that fosters more dynamic group and meaning interactions, thus enabling more sustained collaborative learning and knowledge building.

Introduction

Society is being transformed into an information- or knowledge-based society (Drucker, 1986; ; UNESCO, 2005). The advances and ubiquity of information communication and technology (ICT) provide new forms of connectivity for supporting group work, and transform the traditional notion of learning as individual endeavors into one that also values collective knowledge work (Scardamalia, 2002; Hong & Scardamalia, & Zhang, 2007). In response to this shift in perspective, an emerging line of research on educational technology has been focusing on the design of effective computer-supported collaborative learning (CSCL) environments. The key concept of CSCL is that shared digital environments can be used to foster meaning interactions that produce deeper understanding for the group and its participants; and, as such, the uniqueness of CSCL designs consists in their techniques for supporting effective group collaboration and meaning interaction (Stahl, 2007). Nevertheless, while scholars in general agree the value of CSCL for modern education in a digital age, as an emerging field, there is still much to learn about the nature of CSCL in order to keep designing more effective CSCL environments (Stahl, Koschmann, & Suthers, 2006). As noted by Kreijns, Kirschner and Jochems (2002), "contemporary CSCL environments do not completely fulfill expectations on supporting interactive group learning, shared understanding, social construction of knowledge, and acquisition of competencies" (p.8; see also Kirschner, Strijbos, Kreijns, & Beers, 2004). The question of what constitutes an effective design to support CSCL remains an important challenge in the field.

A conventional design approach to support online collaboration in most CSCL environments has been a theme-based one, i.e., to center group discussion or meaning interaction around themes. A theme can be defined as the subject matter of a conversation or discussion. Oftentimes, themes are pre-determined based on curriculum guideline in order to better structure group interaction. To support theme-based collaboration, many CSCL environments tend to adopt a standardized, threaded discussion design in their discussion boards or forums, with each theme being constructed or represented by means of a thread of continual discussion. For example, as one of the most widely used online learning environments, Blackboard Learning System is designed to support such theme-based collaboration by employing threaded discussion board. Arguably, an important strength of a theme-based design is to help group members focus their discussion and interaction on a specific theme so that deeper understanding of a theme can be achieved. Accordingly, the effectiveness of group collaboration may be measured up by means of the length and quality of thread, e.g., by looking into how and why a discussion thread sustains or dies (Hewitt, 2005). The downside of a theme-based design, however, is that when a theme is being placed at the center of discussion in a thread, the potential meaning interactions or group collaboration between themes (or threads) becomes limited (cf. Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2008). To transform this limitation (while keeping its strength) of a theme-based design, below we propose an alternative idea-centered design approach.

Unlike a theme (which represents a broader area of inquiry), an idea can be thought of as a fundamental unit of information that may be represented by a thought, a cognitive concept, or a proposed solution to a problem, and is formed by the consciousness through the process of ideation (i.e., idea generation). The essential notion of an idea-centered design is to center group discussion or meaning interaction around sustained idea exchange and improvement (Hong & Florence, accepted; Hong, Scardamalia, Messina, & Teo, 2008; Scardamalia, 1999), regardless of whether idea are located in the same thread or not. Doing so is thus able to transform conventionally theme-based threaded discussion into more dynamic meaning interaction. An example of an environment designed as such is Knowledge Forum—a computer-supported knowledge building environment. Knowledge building, as defined by Scardamalia and Bereiter (2003), is a social process focused on the production and continual improvement of ideas of value to a community. In other words, Knowledge Forum as an environment is designed to support group collaboration at a fundamental idea level, rather than at a broader theme level.

To better understand the nature and effectiveness of this idea-centered design approach, the present study compares two digital environments, Knowledge Forum and Blackboard. Our main research question focused on looking into how different design features of each environment might affect how students learn and develop their understanding in the community they belonged.

Method

Context and participants

The present research was conducted in a university course titled "Integrating Instructional Theory and Practice" in Taiwan. The course was offered by the university's Center of Teacher Education as part of its Teacher Education program. It is also the last required course designed to help deepen students' understanding of the relationships between learning theory, teacher expertise, and teaching practice. As their teaching practicum would start right after this course, such understanding became crucial for preparing them to work in authentic teaching context. The university is ranked as one of the best universities in the nation. As such, the students enrolled in the subject university are all academically high-achievers. Based on the test results of the national Basic Competence Test for Senior High School Students (BCTSHSS), in order to enroll in the target university, students' test scores in BCTSHSS need to be ranked above 95 percentile nationwide. However, not all students entered in the subject university are automatically qualified to enter its Teacher Education program. As teaching was a highly respected profession in this country in tradition, there is an additional application and selection mechanism and only limited students with exceptional academic achievements are accepted into the program. Participants in this study were 49 students (25 females and 24 males). Their ages range from 21 to 31 (M=24.02; SD=2.47).

Research design

An essential purpose of this study was to investigate how different design approaches in these two environments, Knowledge Forum (KF) and Blackboard (BB), might affect how students learn and develop their understanding under the same coursework. Knowledge building concept and pedagogy that underlies the design of Knowledge Forum was introduced in class to help students better understand how the activities are designed and what kind of experience of idea improvement they will encounter throughout the whole semester. Except for the difference in the adoption and use of online discussion environments, throughout the whole semester, the teaching conditions and learning activities were purposefully maintained to be as similar as possible (e.g., regular whole-class lecture, group learning activities, individual reading assignments, and invited guest talks, etc.). Therefore, a between-subject design was employed, with about half of participants assigned to the KF group (N=24) and the other half to the BB group (N=25). The KF group was required to use only Knowledge Forum for all online group discussion while the BB group was required to use only Blackboard for their online group discussion.

One thing to note is that Blackboard learning system has been used in the participating university for many years so students were fairly familiar with the interface design and usage of its discussion board. Figure 1 shows two snapshots of the Blackboard learning environment excerpted from the present study. As noted above, threads represent an essential design feature to support group collaboration and meaning interaction in the Blackboard learning environment. As such, much of group interaction mainly occurs within a thread (or a theme[1]), rather than between threads (or themes).

In contrast, it is the very first time that Knowledge Forum was introduced to the students in this course so students were not familiar with its design and use for group collaboration. Therefore, in the beginning of the semester, a tutorial lesson was held in a computer lab. Students were demonstrated the basic design features of Knowledge Forum in order to perform necessary functions, for example, how to create a note or a view (i.e., a multimedia space for group discussion and collaboration) or how to build-on (or reply) to an existing note. Then, they were encouraged to try out themselves. Figure 2 shows a snapshot of a Knowledge Forum view excerpted from the present study in a "basic" text-based mode[2]. It should also be noted, however, that, unlike Blackboard, in which group collaboration can be limited within in a given theme or thread. The idea-centered design of Knowledge Forum allows multiple ways of dynamic group interaction and collaboration, including build-on, reference, annotation, rise-above, co-author, and publication. First, building-on or referencing (i.e., to quote other members' text) is similar to replying notes in a Blackboard discussion board. However, in addition to these tow design features, group discourse and collaboration in Knowledge Forum can also be supported by means of "annotation", which allows users to give short comments within an existing note; "rise-above", which allows users to gather ideas that have already been presented and synthesize or transform these previous ideas into new understandings; "co-author", which means shared authorship of a note; and "publication", which allows users to collaboratively select a note (of high quality) for published status.

Figure 1. Two snapshots of the Blackboard learning environment excerpted from the present study

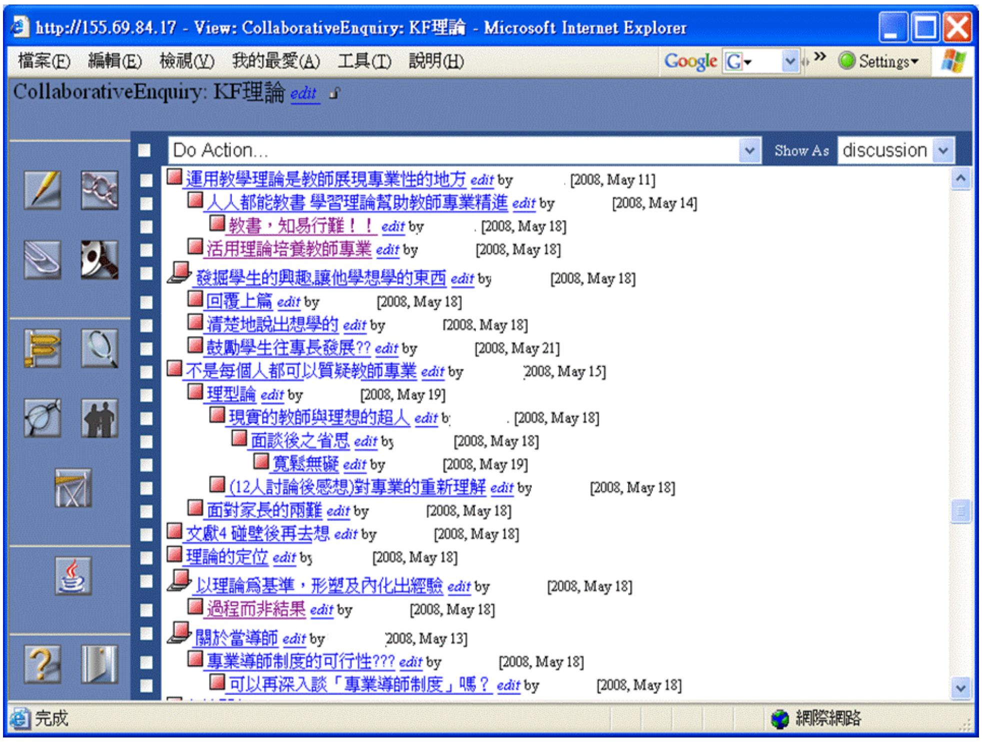


Figure 2. A snapshot of a Knowledge Forum view excerpted from the present study

Instructional design

As an essential instructional goal in this course was to help students gain better understanding of the nature and roles of learning theory and teacher expertise in relation to teaching practice, within each group (KF or BB), students were further divided into two sub-groups: the theory group and the expertise group. As a result, there were four sub-groups being formed in this study: KF-theory, KF-expertise, BB-theory, and BB-expertise. To ensure both "theory" and "expertise" topics were covered for student learning, the two sub-groups within each main group were encouraged to independently pursue the general topic of inquiry (either learning theory or teacher expertise) and then to reciprocally share what they learned with the other sub-group of students (see, e.g., Palincsar & Brown, 1984). The purpose of doing so was to provide a general structure for collaborative knowledge work within each main group, and to ensure not to introduce undesired confounding variables between the two main groups, as the main focus of this study was to compare between the KF and BB environments, in terms of how their different designs scaffold or support group collaboration. Therefore, for the most part of the semester, each of the four sub-groups worked quite independently of one another to advance their group understanding of the overall topic of inquiry.

Data source and analysis

This research employed a mixed approach for data collection and analysis. The rationale is that "the quantitative data and results provide a general picture of the research problem; more analysis, specifically through qualitative data collection, is needed to refine, extend, or explain the general picture" (Creswell, 2005, p.515). Data mainly came from student notes recorded in a Knowledge Forum database (for the KF group) and in a Blackboard database (for the BB group). There were two general types of notes collected. In addition to notes generated from weekly collaborative learning and knowledge-building activities, each participant was also asked to keep a portfolio note. This portfolio note basically served as a high-level thinking scaffold, through which participants were invited to reflect on major changes in their thinking that contributes to their deeper understanding the topic inquired. Another purpose of employing portfolio notes is to make students' own thinking visible for self-assessment (Lee, Chan, & van Aalst, 2006). Further, from a research perspective, these portfolio notes also represent an important data source for evaluating whether there is any important change in student thinking during and after taking this course while using two different online discussion platforms. In terms of procedure, students were required to first re-read all their notes contributed during the semester and then to identify events or activities (e.g., whole-class lecture, reading assignments, guest talks, or online group discussion) that had influence on their conceptual understanding of the topic inquired (e.g., their understanding of the role of teacher expertise in teaching practice).

Regarding data analysis, first, for the quantitative data, a descriptive analysis and a social network analysis were applied to explore participants' online note-contributing behaviors and patterns of social dynamics. Then, an in-depth content analysis was followed to look specifically into participants' portfolio notes, in order to further explore whether and how participants actually deepen their understanding of the topic inquired. Specifically, this content analysis used key concepts identified from students' notes as the unit of analysis. An open-coding procedure based on grounded theory (Strauss & Corbin, 1990, chapter 5) was adopted, with one researcher independently coding all student notes. Resulted from this coding process are nine major themes, which were then further categorized, based on two pre-determined dimensions of change: source and quality. Table 1 shows the nine themes. The occurrences of each theme were then computed for descriptive analysis (Chi, 1997) in order to compare between the KF and BB groups. One thing to note is that the second, third, and fourth major sources of change in Table 1 also represent the primary learning activities originally designed for this course, which are responsible for secondary learning activities (i.e., the first major source of change—peer discussion).

Table 1. Coding scheme based on two dimensions of change: source and quality

Main category		Theme
Source of change	1.	Peer discussion
	2.	Teacher interview transcripts
	3.	Invited guest speaker, instructor and teaching assistant's influence
	4.	Weekly reading assignment
	5.	Others (e.g. individual personal experience and learning processes)
Quality of change	1.	More sophisticated understanding (of the topic inquired)
	2.	Refined understanding
	3.	Naïve or limited understanding
	4.	No sign of understanding demonstrated

Preliminary Findings

Baseline analyses

This study reports preliminary results from partial analysis based on the comparison between two sub-groups: the KF-theory group and the BB-theory group (henceforth the KF group and the BB group). First, for baseline comparison, it was found that the KF group (N=12) in total posted 348 notes (M=29.0) and that the BB group

(N=13) posted 378 notes (M=29.1); there was no significant difference found between the two groups ($F_{(23, 1)}$=.001, p=.973). Moreover, when comparing the total number of words each student produced throughout the whole semester, it was also found there is no significant difference ($F_{(23, 1)}$=2.47, p=.129; M=7231.6 for the KF group and M=6530.1 for the BB group). However, when more specifically looking into how each participant links his or her notes with other participants' notes (i.e., by replying notes in BB vs. by building-on or referencing notes in KF), it was found that there was a marginally significant difference between the two groups ($F_{(23, 1)}$=407, p=.055). In the KF group, there were 263 notes (76% of all notes) that were linked (M=21.9), whereas in the BB group, there were 219 notes (58% of all notes) that were linked (M=16.8). Table 2 summarizes the above results. While the result suggests that there were more note links in the KF environment, this does not really tell us about the group dynamics or social configurations within each sub-group. For example, the pattern of these links can be highly concentrated on a few people in a group, thus indicating a centralized social network structure, or it can be quite the other way around. To resolve this puzzle we further conduct social network analysis (SNA).

Table 2. Online note posting activities between the KF and BB groups

	BB (N=13)		KF (N=12)		F-value	P-value
	M	SD	M	SD		
Number of notes posted	29.10	5.71	29.00	6.84	0.00	0.973
Total Number of words produced	6530	1674	7231	3104	2.47	0.129
Number of notes linked	16.80	0.21	21.90	0.21	4.07	0.055*

* < .10

Social Network Analyses (SNA)

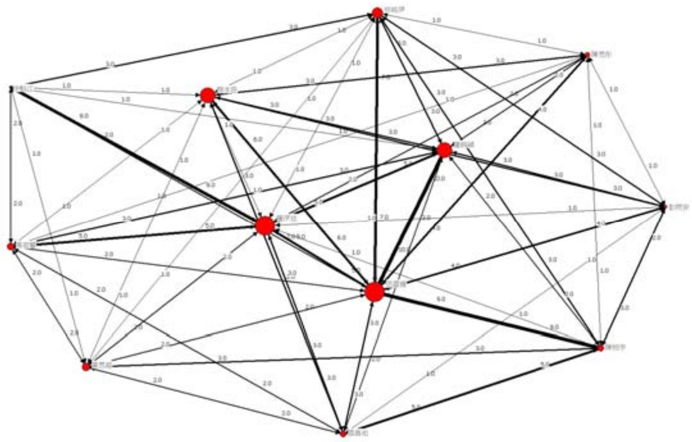
How does idea-centered design support group discourse and collaboration in the KF environment? Table 3 shows how additional design features were exploited by the students in the KF group. As it shows, "annotation" was fairly frequently used by students. A relational analysis further indicates that there was a significant correlation existing between the number of notes linked and that of notes annotated (r =.60, p<.05). This basically suggests that the "annotation" feature has played a supplementary role to support group interactions in the KF environment. As for the "rise-above" feature, while it is less frequently used, as noted above, it played an important role in synthesizing different ideas (regardless where these ideas are located) to form a deeper understanding of an issue or problem. As we manually calculated the total notes being synthesized in each rise-above note, it was found that on average, each rise-above note contains 4.09 notes.

On the other hand, it was found that the remaining two functions, "coauthor" and "publication", were rarely being utilized, which suggests that there is still potential for the participants to develop more sophisticated group interaction and collaboration in the KF environment. Nonetheless, even though all the design features of Knowledge Forum to support collaboration were not fully utilized, based on the results in Table 3, it is still quite obvious that Knowledge Forum served a better environment for facilitating group interactions and collaboration as compared with the Blackboard enabled environment.

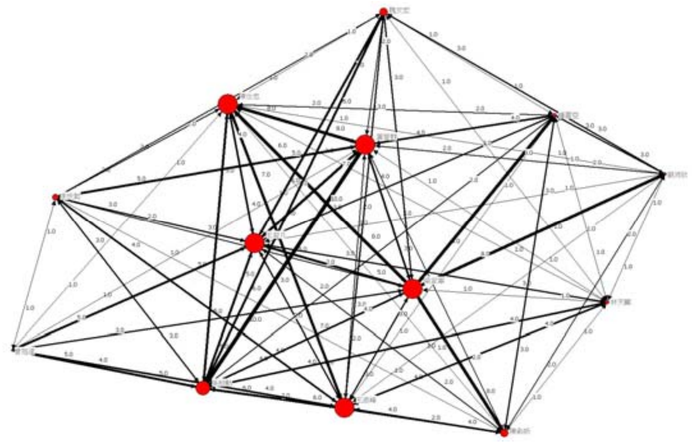
Table 3. Additional design features in support of social interactions in Knowledge Forum

	N	Sum	M	SD
Annotations created	12	48	4.00	3.25
Rise-aboves created	12	11	0.92	0.79
Coauthored	12	1	0.08	0.29
Published	12	0	0	0

To find out if this is the case, we further perform a Social Network Analysis (SNA) to compare the two environments. Figure 4 depicts the group configurations in the KF and BB groups. As expected, both the groups show fairly strong group interactions. But when looking specifically into group dynamics in terms of "betweenness centrality" measure (which basically means an actor's centrality in regulating interaction within a community) and "closeness centrality" measure (which means that the author is close to many others in the network), it was found that the KF group has both a higher "betweenness centrality"[3] value (un-normalized centralization = 23.886; network centralization Index = 1.97%) and a higher "closeness centrality"[4] value (network in-centralization = 35.76%), as compared with the BB group (un-normalized centralization = 23.213, network centralization index = 1.47%; and network in-centralization = 27.41%). Clearly, students in the KF group had more dynamic and close interactions between each other. The next question to ask is whether more dynamic social interactions in the KF group actually produced any quality changes in terms of students' understanding of the topic inquired in this course.



a. Social dynamics within the KF group (N=12)



b. Social dynamics within the BB group (N=13)

Figure 4. The social configurations between the KF and BB groups, both illustrating intense group interaction

Analysis on depth of understanding of the topic inquired

To further look into changes in students' knowledge growth, we further analyze students' portfolio notes. As baseline information, we first compare the total number of words generated in each student's portfolio note and it was found that there was no significant difference between the two groups (F=0.056, P=0.484; M=1307.8 and SD=214.2 for the KB group; M=1470.4 and SD=298.7 for the KF group). We then specifically investigated the following two dimensions of change, i.e., source and quality.

In terms of source, as noted above in "Method," there were five main sources of change, including: (1) peer discussion; (2) teacher interview transcripts; (3) invited guest speaker, instructor and teaching assistant's influence; (4) weekly reading assignment; (5) others (e.g., individual personal experience and learning processes). Table 4 shows the differences between the KF and BB groups in terms of the frequency, percentage, and rank of each source of change. As it shows, as the major source of change, "Peer discourse" accounts a higher percent (42.7%) of changes in the KF group, as compared with 38.6% in the BB group.

Second, in terms of the quality of change, emerged from an open coding procedure were the following four main categories: (1) more sophisticated understanding, (2) refined understanding, (3) naive or limited understanding and (4) no signs of understanding demonstrated. As Table 5 shows, there were more reflective instances (N=56) observed in students' portfolio notes in the KF group that demonstrated deeper change, whereas there were relatively fewer instances (N=41) observed in the BB group (N=41) that demonstrated deeper change.

Table 4. Major sources of change referred by students between the KF and BB groups

Source	KF Group Freq.	KF Group %	KF Group Rank	BB Group Freq.	BB Group %	BB Group Rank
Peer discussion	29	42.7%	1	22	38.6%	1
Teacher interview transcripts	14	20.6%	2	12	21.1%	2
Invited guest speaker, instructor and teaching assistant's influence	13	19.1%	3	10	17.6%	3
Weekly reading assignment	12	17.7%	4	8	14.0%	4
Others (e.g. personal experience)	0	0.0%	5	5	8.8%	5

Table 5. Quality of change in students' depth of understanding (reflective instances as unit of analysis)

Quality of change	KF Group Freq.	KF Group %	BB Group Freq.	BB Group %
1. More sophisticated understanding	56	82.4%	41	71.9%
2. Refined understanding	12	17.6%	16	28.1%
3. Naive or limited understanding	0	0%	0	0%
4. No signs of understanding demonstrated	0	0%	0	0%

One may, however, argue that these instances occurred only among a few students who actually attain deeper understanding in the KF group. To find out if this was the case, we reanalyzed the above dataset, by using "person" as unit of analysis. Table 6 shows the results. As it suggests, 10 out of 12 students (83.3%) in the KF group clearly demonstrated more sophisticated understanding of the main topic inquired during this course. In contrast, there were only 38.4% of students (five out of 13) in the BB group who demonstrated deeper conceptual change in terms of their understanding of the same topic inquired.

Table 6. Quality of change in students' depth of understanding (person as unit of analysis)

Quality of change	KF Group (N=12)	BB Group (N=13)
Deeper change	Students #1, #2, #3, #5, #6, #7, #8, #9, #11, and #12 (10 persons)	Students #1,2,10,12,13 (5 persons)
Preliminary change	None	Students #2, #7, #6, #9 (4 persons)
No change claimed	Student #10 (1 person)	Students #4, #5, #8, #11 (4 person)
Uncertain if there was any change	Student #4 (1 person)	None

An essential purpose of this course is to help students gain deeper understanding of the relationships between learning theory, teacher expertise and teaching practice, and it was frequently observed that students tended to view and describe these three concepts or variables as independent of one another in the beginning of the semester. But towards the end of the semester, the majority of them (see Table 6) were able to elaborate the complex and complementary relationships between these concepts. To demonstrate such quality change in students' thinking, below is an example excerpted from a student's portfolio note:

> After our first group discussion...I realize that theories are a starting point to handle a problem in practice because theories are synthesized from so many cases. Rather than considering theories as a what-to-do tool, we should consider them as a way of seeing problems. We as teachers should learn to use theories properly so that we can improve teacher professional development. Therefore, theories and practices are not separable, they complement each other. (student #6, KF group)

Summary and Discussion

The preliminary results of this study point out different performance patterns between students using Knowledge Forum and Blackboard. In summary, there was a marginally significant difference between the two groups in terms of the number of notes linked. The two indices of group dynamics generated from SNA further showed that there is a stronger interaction pattern in the KF group than in the BB group. Moreover, quantified qualitative difference was also found in terms of the source and quality of change in students' knowledge growth. Overall, the KF group capitalized more frequently on peer discussion than the BB group in pursuit of their new understanding. This is of great importance to an effective CSCL environment in that peer discussion plays an essential role in further deepening and transforming what students learned (e.g., via reading in-service teacher interview transcripts and listening to a talk by an experienced teacher in the present case) into more reflective and refined understanding. One important thing to note is that although the class was composed of a hybrid communication with 2-hour-or-so face-to-face gatherings and intensive online forum discussions on a weekly basis, it was the peer interaction that played the key role to foster students' understanding. As assessed in the present study, by categorizing the degree of changes in student thinking, we found that more students in the KF group than in the BB group demonstrated more sophisticated understanding of the main topic inquired towards the end of this course.

But, to be exact, what might be the mechanism that triggers the depth of idea improvement in Knowledge Forum? Building on the findings, it is conjectured that the rise-above function may have played a key role in this. There are two reasons. Firstly, students in KF group used it nine times and synthesized a total of 57 notes to convert their ideas into more comprehensive viewpoints at the last week. Secondly, rise-above notes congealed the meaning of their discussion when such discussion gradually became too diversified (or too messy). These synthesizing notes turned out to be the collective products as well as a token of community growth in knowledge improvement activities. This conjecture however remains to be further explored and examined. In future and ongoing work, we will employ design-based research to continue looking into how this specific rise-above design feature helps students learn and build knowledge.

An important aim of the present study is to probe into the meaning of the difference under which the two groups utilizing Knowledge Forum and Blackboard environment respectively. As such, this study was largely conducted in a naturalistic situation rather than in a highly controlled experiment setting. Therefore, it remains to be further investigated whether an idea-centered design can be truly held responsible for the effectiveness observed in the present study. To this end, additional ethnographic and video-taping data based on orchestrating the entire classroom activity for at least two hour per week for eight weeks have also been collected. These datasets need to be further analyzed to solve the overall puzzle. For example, these video data consist of many small group face-to-face discussions in class for both the KF and BB groups, which were presumably as critical as many design features in Knowledge Forum. In addition, the whole class presentations took place at the end of the semester (which includes 12 sub-groups) can also serve a rich data source and a great opportunity for further analysis. Admittedly, simply counting the frequencies of notes or links online provides only an incomplete picture of the group dynamics in reality. Further data analyses will be conducted to fully answer the research question.

Endnotes

(1) In the present paper, the terms "thread" and "theme" are used interchangeably to refer to the theme-based design.

(2) Knowledge Forum can also be run under an "enhanced" graphical mode. But in the present study, we only use "basic" mode, in order to make the two environments more comparable.

(3) For betweenness centrality, it is degree a student lies between other students in the community; the extent to which a node is directly connected only to those other nodes that are not directly connected to each other; an intermediary; liaisons; bridges. Therefore, it's the number of people who a person is connecting indirectly through their direct links.

(4) For closeness centrality, it is the degree a student is near all other students in a community (directly or indirectly). It reflects the ability to access information through the "grapevine" of community members. Thus, closeness is the inverse of the sum of the shortest distances between each student and every other person in the community.

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Collaborative Learning in Virtual Seminars: Analyzing Learning Processes and Learning Outcomes

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Abstract: This paper focuses on the analysis of a virtual seminar in respect to learning processes and learning outcomes of its participants who collaborated over a four month period. To investigate the learning processes in this field study, we analyzed the learners' contributions according to four main learning processes: epistemic activities, construction of a conceptual space, dissemination of shared knowledge, and conflict-orientation. To investigate the learning outcome, we analyzed the joint task solutions with respect to knowledge acquisition and knowledge application. Learners were assigned to three groups who had to solve four tasks relating to the main topics on knowledge management. Results show that learning processes varied depending on the tasks and groups, but no general trend was found. Furthermore, the four task solutions also differed in their quality. The fact that learning processes were related to group products confirms the relevance of learning processes for acquiring and applying knowledge.

Learning processes and outcomes in collaborative online learning

Collaborative learning in virtual asynchronous seminars is becoming increasingly common within university settings. From a social-constructivist perspective, collaboration is one important method for learning (Cohen, 1994). The assumption is that during collaboration, learners have to elaborate on their knowledge in more detail (Webb, & Palincsar, 1996), solve socio-cognitive conflicts which arise when learners have conflicting knowledge (Piaget, 1977), and exchange arguments about the best group solution (Andriessen, Baker, & Suthers, 2003). To evoke these positive effects of collaboration, it is necessary to design powerful learning environments (De Corte, 2003). On a didactical level, such collaborative learning environments may include, for example, tasks which necessitate the interdependent collaboration of all group members (Johnson, & Johnson, 1992), groups with an appropriate number of members between 2 and 5 (Lou, Abrami, & d'Appollonia, 2001), or didactical design principles such as problem-based learning (Dochy, Segers, Van den Bossche, & Gijbels, 2003, Koschmann, Kelson, Feltovich, & Barrows, 1996). This specifically involves four design principles which may help motivate learners in their learning processes: the integration of authentic problems that illustrate the relevance of the subject for real-life cases, multiple perspectives for showing different points of view, collaborative learning, and scaffolds to support learners in their knowledge acquisition (Reinmann, & Mandl, 2006). All of these design principles are relevant for both face-to-face and virtual collaboration even though there may be a few differences concerning the actual collaboration itself. Such differences mainly involve the method of communication, because the contributions in virtual environments are not spoken, but typed. Typing contributions may improve performance (Jonassen, & Kwon, 2001) for the following reason: Learners not only have more time to reflect on their own contributions, but may also reflect longer on the contributions of other group members – and this on a high level (Thomas, 2002). Therefore, contributions in virtual environments may be more detailed than those in face-to-face collaboration (Althaus, 1992). Due to this fact, virtual collaboration may facilitate deeper and more intensive learning.

To verify this assumption, it is necessary to have a closer look at specific *learning processes* and *learning outcomes* in virtual learning environments that involve knowledge acquisition as well as knowledge application (De Corte, Verschaffel, Entwistle, & van Merrienboer, 2003). The following cognitive activities are important for learning processes:

First of all, *epistemic activities* are a very important indicator of the learner's level of concentration on task-relevant aspects (Fischer, Bruhn, Gräsel, & Mandl, 2002). Learners in virtual learning environments are more involved than learners in face-to-face scenarios (Kiesler, & Sproull, 1992). Epistemic activities are mainly subdivided into content-specific and coordination-oriented processes (Bruhn, 2000). Learners who engage in elaborating and discussing the content and theoretical concepts they are confronted with should be better at acquiring and applying knowledge (Cohen, 1994). Coordination-oriented processes comprise all activities which are necessary for solving the task collaboratively while discussing and agreeing on the procedure. These activities are not necessarily beneficial for learning, but they are necessary if learners do not automatically know how to solve a task collaboratively. Studies on supporting computer-supported collaborative learning reveal that this is often the case (Fischer, Kollar, Mandl, & Haake, 2007).

A *second* aspect concerns the *construction of a conceptual space or problem space*, which is especially important in computer-supported collaborative learning (Teasley, & Roschelle, 1993). As Roschelle and Teasley

(1995) emphasize, “collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem” (p. 70). According to this perspective, learners solve their problems collaboratively in a “negotiated and shared problem space” (p. 70) which is constructed through joint activities that occur when working on a task. These include the identification and naming of theoretical concepts which are relevant for task solution (Weinberger, 2003). At the same time, constructing a joint problem space is a necessary prerequisite for grounding (Clark, & Brennan, 1991) as an indication of joint comprehension. Only when learners understand each other are they able to co-construct knowledge and solve a task together.

The *third* activity, the *dissemination of knowledge*, is very closely related to the construction of a conceptual space. This is a key aspect of collaboration: Collaboration can only take place when knowledge is disseminated among the collaborating partners (Kopp, & Mandl, 2006). In this context, it makes sense to look more closely at the information pooling paradigm (Stasser, & Titus, 1985, Wittenbaum, & Stasser, 1996). This focuses on the phenomenon that group members often simply name and repeat shared information and do not disseminate unshared information. Even though it was assumed that virtual learning environments could compensate for such effects through collaboration, studies showed no difference between virtual and face-to-face collaboration (Hollingshead, 1996). Therefore, it is necessary to have a closer look at the knowledge disseminated in the learner’s contributions. But even this analysis alone may not prove sufficient, because even when learners disseminate knowledge, the knowledge is not necessarily considered and processed further as part of the task’s solution. This is due to learner’s preference-consistent evaluation of information (Greitemeyer, & Schulz-Hardt, 2003). Thus, consideration must be given to both the knowledge that is disseminated during collaboration and the knowledge that is integrated into the task solution.

A *fourth* learning activity is manifested in *conflict-orientation*. According to Piaget (1977), confronting different perspectives and knowledge stimulates learning as a result of socio-cognitive conflicts. Such conflicts may disturb the learner’s cognitive equilibrium. Learners then aim to restore this cognitive equilibrium again. One way of achieving this is through intensive cognitive processing that leads to local coherence and a deeper understanding of the subject matter (De Lisi, & Goldbeck, 1999). This approach focuses on the development and resolution of socio-cognitive conflicts. Doise and Mugny (1984) found that learners who are engaged in socio-cognitive conflicts provoked by critical statements elaborated their knowledge more deeply and were therefore more successful in acquiring knowledge. Both the number of socio-cognitive conflicts and their manner of resolution are important aspects of effective knowledge acquisition (Nastasi, & Clements, 1992).

Analyzing the group product in the form of the task solution is one main method of measuring *learning outcome* (Slavin, 1995). The group product shows how effectively and successfully the learners have collaborated. This indication of the learning success may be analyzed in different ways (De Jong, & Ferguson-Hessler, 1996). Cued and free recall provide one way of investigating the acquisition of conceptual knowledge (Reiserer, 2003). Another method involves using cases to analyze the application of situative knowledge (Fischer et al., 2002). Both knowledge acquisition and knowledge application are especially important when looking at group products in problem-based learning environments, (De Corte, 2003). Therefore, when analyzing group products as task solutions, both the learned concepts and their application to a specific problem are relevant. In this respect, the case analyses should include theoretical concepts and the quality of the case solution.

Both learning processes and learning outcomes may change during collaboration. The longer learners collaborate, the more they grow accustomed to it. This implies that learning processes and learning outcomes improve over time. More specifically, content-specific epistemic activities increase over time, while coordination-oriented activities decrease: when learners get used to collaborating, they know how to proceed and coordinate their activities. Therefore, they have more capacity to elaborate on content-specific aspects and spend less time discussing their coordination. Furthermore, the negotiation efforts surrounding a shared problem will improve as well as learner’s effectiveness in disseminating knowledge. The better the learners get to know each other, the less they fear offending other group members when counter-arguing or criticizing. Lastly, it is assumed that group products improve over time as a result of better collaboration.

Questions and hypotheses of the study

Based on our theoretical considerations, there are three main questions concerning learning processes, learning outcomes and their relationship to one another.

(1) To what extent do learning processes occur in virtual seminars? It is assumed that learners will be highly involved in all four learning processes: epistemic activities, conceptual space, dissemination of shared knowledge and conflict-orientation. In addition, we hypothesize that they change and improve over time.

(2) To what extent does the quality of group products change over time? Because learners gain experience in collaborating over time, we hypothesize that the quality of group products will improve during the course of the seminar.

(3) Is there a relationship between the learning processes and the learning outcome in virtual seminars? We expect that learning processes and learning outcome are related: We expect to observe a positive correlation between collaborative learning outcome and content-specific epistemic activities (Cohen, 1994), conceptual space (Rochelle, & Teasley, 1995), shared knowledge (Rochelle, & Teasley, 1995), and conflict-orientation (Piaget, 1977).

Method

Sample and Design

The participants of the field study included the undergraduates of the University of Munich who were enrolled in the virtual seminar "Introduction to Knowledge Management" during the winter term 2002/2003. Eight females and five males were divided into three groups: two groups with four members and one group with five members. To help prevent the group members from meeting face-to-face, the groups were formed according to the residences that were furthest away from one another.

Learning Environment

Tasks

Learners who participated in this seminar had to collaborate with one another during the whole semester. Learners were mainly tasked with acquiring knowledge on the four topics of "knowledge representation", "knowledge communication", "knowledge generation", and "knowledge use". The tasks assigned were provided in the form of cases. Each case described problems that various companies faced relating to knowledge management. All cases were subdivided into two tasks: In the first task, learners were asked to collect the information provided on the topic (conceptual knowledge). In the second task, learners had to actively construct new knowledge by applying the knowledge acquired (situative knowledge). Each of the cases required a different method of analysis depending on the topic. In the case on "knowledge representation", learners were to investigate the main problems relating to knowledge representation in organizations and search for different solutions. The case on "knowledge communication" provided a basis for identifying the functions and characteristics of knowledge communication as well as barriers to knowledge communication. Furthermore, learners had to define a concept for initiating a community of practice. The third case was conceptualized to encourage various methods of knowledge generation and their implementation. In the last case, a learning center had to be evaluated on the basis of the methods for knowledge use.

Didactics

The learning environment was didactically designed according to problem-based principles. These included the learner's collaboration throughout the whole semester and the joint case solution. The cases were developed according to authentic knowledge management-related problems present in different companies. To additionally support learners in the virtual seminar, they received information on each topic and collaboration rules.

Technical Realization

The learning environment consisted of features such as a user interface or HTML-pages, and threaded discussion boards with the potential for users to upload and download files. Access to the learning environment was provided via the World Wide Web and saved by personal login data. The home page described the basic structure of the seminar with a timetable and news ticker. The navigation bar on the left side included general information about the seminar, and all specific topics relating to the content of the seminar. In addition, communication with the tutor was made possible via a question board.

Schedule and procedure

Every semester, this virtual seminar is offered to undergraduates. The data from this seminar was taken from the winter term 2002/2003. The seminar consisted of four phases:

- *Presentation and exploration*: During the first week, learners were invited to introduce themselves to the other participants in the seminar. Time was also taken to explain the learning environment, present the course schedule, and discuss the problems relating to collaborative learning in asynchronous scenarios. During this phase, learners should become acquainted with one another.
- *Clarification and coordination*: The first task for the three groups involved explaining the term "knowledge". As this was the first task to be solved collaboratively, it was necessary to stress the overall coordination of the group for future collaboration. The members should start to feel like a group and act as a group.
- *Collaborative knowledge acquisition*: This phase was the core element of the seminar. Learners had to work collaboratively to solve four cases about knowledge management (see above). Learners were

given 12 days to complete each topic. Learners communicated via the learning environment in discussion forums. Each group had access to its own forum (see figure 1). In this phase, learners should acquire most of their knowledge about knowledge management.

- *Reflection and fading*: In the last phase, learners again worked systematically on the four topics of the seminar to summarize the relevant aspects and to integrate them into a complex overall picture. This phase was intended to stimulate deep learning processes and encourage participants to draw inferences between the individual topics and to construct a mental schema about knowledge management.

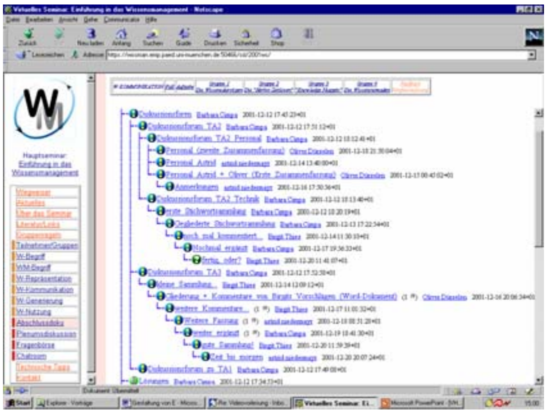

Figure 1: Example of a discussion forum.

Data collection

Several different methods were developed for collecting data to evaluate the virtual seminar. First of all, participants were asked to fill in *questionnaires* to evaluate aspects relevant to collaboration, namely pre-knowledge, motivation, attitude towards group work, attitude towards virtual learning and computer experience. Learners selected from a five-point Likert scale from “totally agree” to “disagree”. The Cronbach’s Alpha was .61 for pre-knowledge, .65 for motivation, .58 for attitude to group work and virtual learning, and .65 for computer experience. The questionnaire was developed according to Naumann and Richter (2001) and Stark (1999).

In a second step, the *learning process* was analyzed with respect to epistemic activity, conceptual space, dissemination of shared knowledge, and conflict-orientation. To achieve this, all written contributions were rated according to a coding scheme. The contributions were then validated by a second evaluator who assessed 20 per cent of all contributions. The inter-rater agreement was with r >.96 satisfying.

Epistemic activities included all the contributions which were related to the task and the task-solving process. These were subdivided into content-specific and coordination-oriented epistemic activities. A contribution was labeled as content-specific when it was connected to a theoretically based discussion. This means that all statements which were related to the discussion of the content were rated as content-specific. All statements which were necessary for temporal, structural and personal coordination were categorized as coordination-oriented. These contributions were part of the planning and organization of the group work. All kinds of social talk were considered to be non-epistemic. To analyze the number of epistemic activities, all contributions were divided into propositions and relativized based on their number of words.

The amount of theoretical concepts which were relevant for the task solution was labeled as *conceptual space*. These concepts were part of the theoretical knowledge which was provided by the learning environment (e.g. texts on each specific topic). First, we counted all the different theoretical concepts of each individual task and group. Secondly, we wanted to identify how many of these theoretical concepts were new ones and how many were from previous tasks. To compare the three groups, we calculated this value in per cent.

Dissemination of shared knowledge was analyzed in two steps: All the theoretical concepts mentioned in the individual contributions and in the group product were counted. The theoretical concepts were again provided by the learning environment (e. g. texts on each specific topic). Afterwards, the ratio between these two measures was used to analyze the group’s efficiency in disseminating and re-using knowledge for task solutions.

All critical contributions or suggestions for improving the task solutions were rated as *conflict-orientation*. These statements aim at showing disagreement with the task solving process or the task solution. Here, only epistemic talk was coded, not social talk.

In a third step, the *collaborative knowledge outcome* was collected by analyzing the group product according to conceptual and situative knowledge (De Jong, & Ferguson-Hessler, 1996). The conceptual knowledge referred to the content-specific knowledge learners had acquired (knowledge acquisition). Each individual and correct theoretical aspect received one point. Then all the points were summed up to one score. The situative knowledge measured the quality of the problem solving task (knowledge application). Here experts rated the amount of problem-solving power the group product had.

Results

Treatment Check

Before we look at the results of our research questions, we wanted to know whether the three groups were comparable in various aspects relevant to collaboration. To do this, we looked at the group's pre-knowledge, motivation, attitude to group work and virtual learning, and experience with computers (see table 1). As can be seen from the data, the three groups did not differ in these characteristics.

Table 1: Pre-requisites of the learners in the three groups from 1 to 5 (max. 5.00)

	Group 1 *M (SD)*	Group 2 *M (SD)*	Group 3 *M (SD)*
Pre-knowledge	2.50 (*.79*)	2.08 (*.32*)	2.13 (*.61*)
Motivation	4.75 (*.50*)	4.75 (*.29*)	4.50 (*.50*)
Attitude to group work	4.31 (*.77*)	4.25 (*.65*)	4.25 (*.40*)
Attitude to virtual learning	3.42 (*1.07*)	3.42 (*1.23*)	4.20 (*.77*)
Experience with computers	3.88 (*.97*)	4.13 (*.72*)	4.35 (*.73*)

Research Question 1

For analyzing group work, we investigated the individual contributions of every group according to relevant processes. We concentrated our analyses on epistemic activities, on the construction of a conceptual space, on the dissemination of shared knowledge and on conflict-orientation.

Epistemic activities. We divided epistemic activities into content-specific and coordination-oriented epistemic activities. All contributions which were not related to the case were considered non-epistemic activities. As we can see in table 2, non-epistemic activities were low in all cases and lowest in cases 2 and 3. They were highest in the first case solution. It is possible that participants exchanged social information in the beginning to get to know one another better. Furthermore, we can see in almost all groups (with the exception of group 3 in task 2) that content-specific epistemic activities were highest in cases 2 and 3, while coordination-oriented epistemic activities were lowest in these cases.

Table 2: Epistemic activities in per cent for each group in the 4 cases

	Content-specific				Coordination-oriented				Non epistemic			
	Case 1	Case 2	Case 3	Case 4	Case 1	Case 2	Case 3	Case 4	Case 1	Case 2	Case 3	Case 4
Group 1	48.62	68.84	55.83	45.56	41.23	27.99	41.32	52.49	10.15	3.17	2.85	1.95
Group 2	28.13	65.69	67.18	38.83	54.46	26.46	27.10	46.17	17.41	7.85	5.72	15.00
Group 3	47.26	39.87	52.84	33.39	45.80	54.94	43.10	59.74	6.84	5.19	4.06	6.87

Construction of a conceptual space. To more closely investigate the conceptual space, we first analyzed the number of new theoretical concepts for each of the four different cases. The three groups did not exhibit a general trend relating to mentioning new concepts in respect to time or case in either the conceptual knowledge task or in the situative knowledge task. We only can see that overall group 2 contributed more theoretical concepts than group 1 or group 3 (see table 3).

Table 3: Total numbers of new theoretical concepts as an indicator of conceptual space in the 4 cases for each group divided into conceptual (CK) and situative (SK) knowledge tasks

	Case 1		Case 2		Case 3		Case 4	
	CK	SK	CK	SK	CK	SK	CK	SK
Group 1	24	25	19	33	23	14	28	8
Group 2	28	21	46	42	30	29	34	32
Group 3	30	29	34	31	25	15	24	22

In a second step, we measured how many of the theoretical concepts mentioned were new (see table 4).

Table 4: New theoretical concepts as an indicator of conceptual space in the 4 cases for each group in per cent divided into conceptual (CK) and situative (SK) knowledge tasks

	Case 1		Case 2		Case 3		Case 4	
	CK	SK	CK	SK	CK	SK	CK	SK
Group 1	100	100	84.2	75.8	69.6	57.1	89.3	100
Group 2	100	100	78.3	97.2	66.7	65.5	61.8	90.6
Group 3	100	100	88.2	80.6	60.0	60.0	87.5	63.6

In tasks 1 and 2, learners mostly mentioned new theoretical concepts. Because the first case involved a new topic, it is evident that 100 per cent of the theoretical concepts mentioned in the first task were totally new. The least number of new concepts were used in case 3, whereas in the fourth case the number of new concepts increased again.

Dissemination of shared knowledge. It is necessary to analyze the dissemination of shared knowledge to evaluate how effective groups were in integrating their knowledge into their joint group product. As table 5 shows, the ratio between the theoretical concepts disseminated in individual contributions to those used in the group product was highest in group 1 and lowest in group 2. There was no general increase in efficiency over time, but groups 1 and 3 were least efficient in the first case.

Table 5: Dissemination of theoretical concepts in contributions and group product and the ratio between them as an indicator for shared knowledge in the 4 cases for each group

	Case 1		Case 2		Case 3		Case 4	
	CK	SK	CK	SK	CK	SK	CK	SK
Group 1								
Contributions	24	25	19	62	23	14	28	8
Group product	21	25	19	62	23	14	28	8
Ratio	.88	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Group 2								
Contributions	28	21	46	42	30	29	34	32
Group product	24	18	22	18	25	15	23	31
Ratio	.86	.86	.48	.67	.83	.52	.68	.97
Group 3								
Contributions	30	29	34	31	25	15	24	22
Group product	27	22	34	31	15	15	24	22
Ratio	.90	.76	1.00	1.00	.60	1.00	1.00	1.00

Conflict-orientation. There was not an increase in conflict-orientation of the three groups during the virtual seminar as an indicator of the deep elaboration of knowledge. We can only see that group 2 differs from group 1 and 3 in the total amount of conflict-oriented statements (see table 6).

Table 6: Conflict-orientation in the 4 cases divided into the conceptual knowledge (CK) and situative knowledge tasks (SK) of each group in absolute numbers

	Case 1		Case 2		Case 3		Case 4	
	CK	SK	CK	SK	CK	SK	CK	SK
Group 1	2	4	0	5	1	2	3	0
Group 2	6	3	5	4	7	5	3	2
Group 3	4	5	2	5	2	5	1	1

Research Question 2

In research question 2, we were interested in the quality of the group products. We analyzed conceptual and situative knowledge separately. When investigating conceptual knowledge, all groups exhibited almost the same level of quality in all four cases (see table 7). There was no increase in quality over time.

When investigating situative knowledge - the knowledge application task - the groups differed in their knowledge with respect to the cases (see table 7). All the groups performed better in cases 2 and 3 than in cases 1 and 4 for both conceptual and situative knowledge.

Table 7: Quality of group products in conceptual and situative knowledge (both maximum 10)

	Conceptual knowledge				Situative knowledge			
	Case 1	Case 2	Case 3	Case 4	Case 1	Case 2	Case 3	Case 4
Group 1	5	8	7	5	4	9	6	3
Group 2	4	6	7	5	4	7	8	4
Group 3	5	5	6	6	6	7	6	5

Research Question 3

We identified some significant correlations between the learning processes and the group product (see table 8). Situative knowledge was positively related to content-specific epistemic activities and negatively related to coordination-oriented epistemic activities (Cohen, 1994). Furthermore, situative knowledge was also highly positively correlated to conceptual space and conflict-orientation.

Table 8 Correlations (Spearman-Rho) between learning processes and group product

	Conceptual knowledge	Situative knowledge
Epistemic activities: Content-specific	.02	.67**
Epistemic activities: Coordination-oriented	.34	-.53*
Conceptual space: total number of concepts	.09	.57*
Conceptual space: total number of new concepts	-.37	-.19
Knowledge dissemination	.38	-.23
Conflict-orientation	.01	.74**

Annotation. * = $p < .05$; ** = $p < .01$; $n = 12$.

Summary and discussion

In this field study, we investigated the learning processes and learning outcome of three groups of learners during a virtual seminar. To ensure the comparability of the three groups, we looked at differences in the learner's pre-knowledge, motivation, attitude to group work and virtual learning, and experience with computers. We did not identify any differences between the three groups. As this is a case study in the field with a very small number of groups, the results are more a starting point for future investigation than generalizable on other virtual learning environments.

Firstly, we had a closer look at *learning processes*. To do this, we analyzed all of the contributions typed by the group members in a very detailed way. We could not identify a general time-related trend for the three groups with respect to the four categories of epistemic activities, creating a conceptual space, dissemination of shared knowledge and conflict-orientation. As a general rule, collaboration was influenced by the task itself and not by the learner's potentially increasing collaboration and task-solving abilities. But when we look at the process analyses in more detail, there are some interesting findings. With respect to epistemic activities, all learners were highly involved in the task-solving activity, so that, with the exception of the first case, social or off-task talk was very low. This may be due to the fact that learners first wanted to get to know each other better before collaborating more intensively. Content-specific and coordination-oriented epistemic activities were mostly reciprocal: If the number of content-specific activities was high, the number of coordination-oriented activities was at least 20 per cent less than content-specific activities and vice versa. Especially in cases 2 and 3, content-specific activities were highest, while coordination-oriented activities were lowest. For case 2, this could be supported by the fact that the highest total number of new theoretical concepts were presented in this case for creating a conceptual space. When we have a further look at the group efficiency, we see that in the first case, all groups had difficulties in making the knowledge from the contributions useful for the group product. In the cases that followed, the ability to collaborate efficiently increased for groups 1 and 3, but not for group 2. Evidently groups 1 and 3 had better collaboration strategies than group 2, which did not perform as well. In general, we found a relatively low number of conflict-orientated utterances, which replicates the results of experimental studies in which learners engage in knowledge acquisition (Reiserer, 2003) or in knowledge application (Fischer, et al., 2002). Perhaps, learners are afraid of offending group members when expressing disagreement with their contributions or when criticizing them on a task-level.

In a second step, we investigated the four *group products*. Conceptual and situative knowledge increased or decreased depending on the case, but did not continually improve. Overall, group 1 performed best in the acquisition of conceptual knowledge and group 3 performed best in the acquisition of situative knowledge. The quality of the group product was best in cases 2 and 3. Evidently, when the groups are first formed, they do not work as effectively as in cases 2 and 3. The reason why learners did not perform as well in the last case may be due to their other duties as students. Clearly this would not be a factor for learners participating in a laboratory experiment. At the end of the semester, the students had to take tests (Schnurer, 2005) which reduced their time and cognitive capacity for solving the cases in the seminar. It is also possible that learners were not as motivated to participate so intensively in the case-solving process at the end of the semester.

When investigating the *correlations between learning processes and learning outcomes*, only situative knowledge is significantly related to learning processes, not conceptual knowledge acquisition. We identified four main correlations. Epistemic activities were positively related to situative knowledge as long as they were content-specific. When learners engage more in content-specific aspects, their collaborative learning outcome in situative knowledge improves. But when they engage in coordination-oriented activities, the quality of the group product suffers. When learners engage in the subject matter, i.e. when they discuss and elaborate main aspects of a topic, their group product can profit from this deep cognitive involvement. Coordination is necessary for collaboration, but it does not improve the quality of the group product. This is due to the fact that coordination is not related to content elaboration, but to the way in which learners should proceed in solving their task. The total number of theoretical concepts mentioned in the contributions is deeply connected to situative knowledge acquisition. The group product improves when learners mention more adequate theoretical concepts in their contributions. This is the case, because when an increased number of concepts is disseminated, there is a greater opportunity for learners to integrate them into the group product. Furthermore, conflict-orientation is also related to situative knowledge. The quality of the learner's solution improved in cases where learners spent more time critically discussing content-specific aspects. Socio-cognitive conflicts stimulated by disagreement can also improve problem-solving (Doise, & Mugny, 1984).

When we take a closer look at the *three groups* and compare them with one another, we can see that groups 1 and 3 differed from group 2 in some respects. When analyzing the learning processes between the groups, we see that group 2 was more engaged in content-specific activities and in the dissemination of theoretical concepts for cases 2 and 3 than groups 1 and 3. But when we have a closer look at group efficiency, group 2 was least efficient. Despite this fact, the quality of their group products was not worse than the group products of groups 1 and 3. Furthermore, group 2 made a lot of conflict-oriented utterances; however, these especially came about when working on tasks for conceptual knowledge, and not when working on tasks for situative knowledge. Only conflict-oriented utterances relating to situative knowledge are positively correlated with group performance. For this reason, we can conclude that the learning processes of group 2 were not as efficient as the ones of groups 1 and 3. In one respect, this group showed a lot of effort in their collaboration, but was not successful in their group products. This is because they were too conflict-oriented in knowledge acquisition tasks, but not in knowledge application tasks.

For sure, all these results are just a starting point for future research. In fact, even though we had a very small sample, we did quantitative analyses, no qualitative analyses to get a deeper insight into online collaboration. Future studies should include a bigger sample and qualitative data as additional material to deeper illustrate collaboration. Furthermore, different kinds of data analyses could be conducted with a bigger sample.

Conclusions

Overall, the analysis of the collaboration in virtual seminars showed very complex cognitive processes. Learning processes changed over time depending on the task. In fact, content-specific epistemic activities as well as the engagement in theoretical concepts and conflict-orientation are relevant for the learner's success in collaboration. This is a very important finding, because to date, such results were only found in experimental conditions (Bruhn, 2000, Fischer et al., 2002, Reiserer, 2003). In addition, as we have seen in the group comparison, different learning activities influence the collaborative task-solving process. Further instructional support can especially focus on improving these learning activities. There are two main potential methods: conducting a training in collaboration before the virtual sessions (Rummel, & Spada, 2005) or using scripts, which could be directly implemented in the virtual learning environments (e. g. Weinberger, Ertl, Fischer, & Mandl, 2005). This investigation has provided further insights into virtual collaboration in real learning settings.

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The Effects of Corrected-Errors in Asynchronous Video Based Lessons on Task Efficiency

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Abstract: This study explores the impact that student exposure to instructor made corrected-errors can have on their pedagogy through the use of asynchronous video-based lessons. We define corrected-errors as segments in the lesson where the instructor makes an error, identifies that an error has been made, and then goes on to correct it. Our study measures the learners' performance on a similar task by looking at the efficiency in which that task is carried out. We hypothesize that the modeling of error detection and correction skills when coupled with the instructor's explicit meta-cognitive explanation and reflection of errors, will lead to an increase in efficiency.

Introduction

This study explores the impact that student exposure to instructor made corrected-errors can have on their pedagogy through the use of asynchronous video-based lessons. Asynchronous video-based lessons are prerecorded instruction that the viewer can watch on demand. We define corrected-errors as segments in the lesson where the instructor makes an error, identifies that an error has been made, and then goes on to correct it (Antonios Saravanos, 2008a). Our study measures the learners' performance on a similar task by looking at the efficiency in which that task is carried out. We hypothesize that the modeling of error detection and correction skills, especially when coupled with the instructor's explicit meta-cognitive explanation and reflection of errors will lead to an increase in efficiency.

Theoretical Framework

Originally psychologists such as (Thorndike, 1927) and (Skinner, 1968) asserted that any erroneous knowledge that is taught by the instructor to the learner would have to be unlearnt before the correct information could be taught. However, this notion was to change when (Fisher & Lipson, 1986) stated that errors are only undesirable when they deter a student from learning the material thus expanding on the notion that errors could possibly have a place in pedagogy. Their belief was founded on the idea that the learning of meta-cognitive skills could have a positive effect on future performance. This notion was further built on by (Marcone & Reigeluth, 1988) who extended on this idea by investigating the effects that teaching students about common errors would have on their pedagogy. A plethora of studies have been conducted that provide evidence that error training can have positive effects on learning (Berkson & Wettersten, 1984; Chillarege, Nordstrom, & Williams, 2003; Gully, Koles, Payne, & Whiteman, 2002; Ivancic & Hesketh, 1995). However little research has been conducted looking at the effect of errors in asynchronous video based lessons (A. Saravanos et al., 2008).

Method

A three group post-test only experimental design was used to study the aforementioned hypothesis and was adapted from (Antonios Saravanos, Paek, & Kuwata, 2009) and (Antonios Saravanos, 2008b) to look at the ways in which a corrected-error could appear in instruction and its effect on learner efficiency on transfer activities. The two ways in which a corrected-error could appear in instruction were with and without explanation as to the instructor's error detection and correction process. A third group that did not contain any corrected-errors was used as a control to determine the effect of the errors. Three instructional videos were then designed to teach novices how to use a Web Development Environment to create web pages. The Web Development Application that was chosen was Macromedia Dreamweaver 8.

Participants

The participants in this study were graduate students studying in the New York City area. Participants were asked to only participate if they did not have any prior experience utilizing a Web Development Application.

Design of the Videos (Independent Variable)

In the first video, that represents instruction that contains no errors (NE) the instructor covers the steps needed to create a webpage in Dreamweaver 8. In the second video that represents instruction that contains corrected-errors (CS) the teacher covers the same curriculum but completes the task with five errors that are often made during the process and corrects the errors without any explicit explanation and reflection on how s/he learns from those errors. The third video contains corrected-errors followed by the instructor's meta-cognitive knowledge (CW), the teacher covers the same curriculum with the same five errors in video one while demonstrating the process of detecting, correcting errors and explicitly explaining the troubleshooting process and reflecting on how they learn from those errors. The videos were created by taping the CW lecture and then editing the footage to achieve the CS and NE lectures. A screen capture showing what an example of how the lesson looked can be seen in Figure 1.

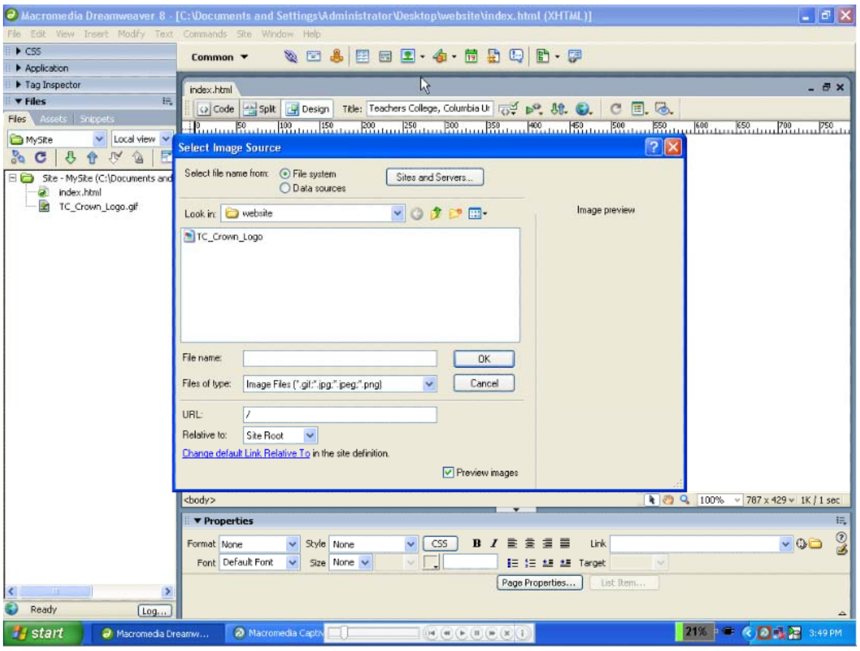

Figure 1. Screen capture from one of the video lessons.

Procedure

A series of experiments were performed to measure the effect of the irregular instruction on learner interaction and performance. Experiments were held in a quiet room that would resemble the same conditions as would be experienced by a person learning through asynchronous instruction at home. The control group and the two experimental groups watched video 1 (NE) and videos 2 (CS) and 3 (CW), respectively. All necessary materials such as pictures and texts were provided. They were allowed to pause, rewind the video and take notes. Following the viewing of the video each participant was required to complete an exercise task, which was similar with the one in the movie. The following steps took place:

1. The experimenter provided the participant with a laptop containing one of three aforementioned videos to watch. Participants were allowed to spend up to one and half hours to watch the video, and were told that they may pause, rewind, or fast-forward the video as desired.
2. Participants were then asked to try and solve a transfer problem that required them to create a simple web site using the techniques that had been taught in the lesson.

Measures (Dependent Variable)

Student performance was measured by observing the number of errors that each participant made on the transfer activity, their detection of any errors, and their ability to correct any errors that were detected. An efficiency score was calculated from those observations where 0 represented the lowest score possible and most inefficient performance on the transfer activity. Conversely 15 represented the most efficient performance on the transfer activity.

Results

The results are categorized in two areas: transfer activity efficiency and participant ability to detect and correct errors on the transfer activity.

Transfer Activity Efficiency

A one-way analysis of variance showed that learner performance on the transfer task was significantly affected by the addition of both types of CE into the instruction, $F(2, 48) = 7.630$, $p = .001$. The mean scores and variances can be seen summarized in Table 1. These results showed that learning varied between the groups with a possible minimum score of 0 and a maximum score of 15. The NE group had a mean score of 11.470 and a standard deviation of 2.125, the CS group had a mean score of 7.240 and standard deviation of 4.131, and the CW group had a score of 10.180 and a standard deviation of 3.147. The minimum scores that were observed were 6, 0, 5, and the maximum scores were 14, 15, 15, for Groups NE, CS, and CW respectively.

Table 1: A summary of the efficiency scores on the transfer activity by group.

	N	Min	Max	Mean	Std. Dev
NE	17	6	14	11.470	2.125
CS	17	0	15	7.240	4.131
CW	17	5	15	10.180	3.147

To ascertain which groups' performance differed three independent t-tests were carried out. When comparing the scores between the NE and CS groups, the Levene's Test for Equality of Variances yielded an F-score of 6.308 ($p = 0.017$). Therefore, an equal variance was not assumed for the two groups. The t-test produced a t-score of 3.759 ($p = 0.001$) that was significant. When comparing the scores between the CS and CW groups, the Levene's Test for Equality of Variances yielded an F-score of 0.957 ($p = 0.335$). From these results we assumed an equal variance for the two groups. The t-test yielded a t-score of -2.335 ($p = 0.026$) that was significant. When comparing the scores between the NE and CW groups, the Levene's Test for Equality of Variances yielded an F-score of 3.487 ($p = 0.071$). Again from the results we assumed an equal variance for the two groups. The t-test yielded a t-score of 1.405 ($p = 0.171$) that was almost significant.

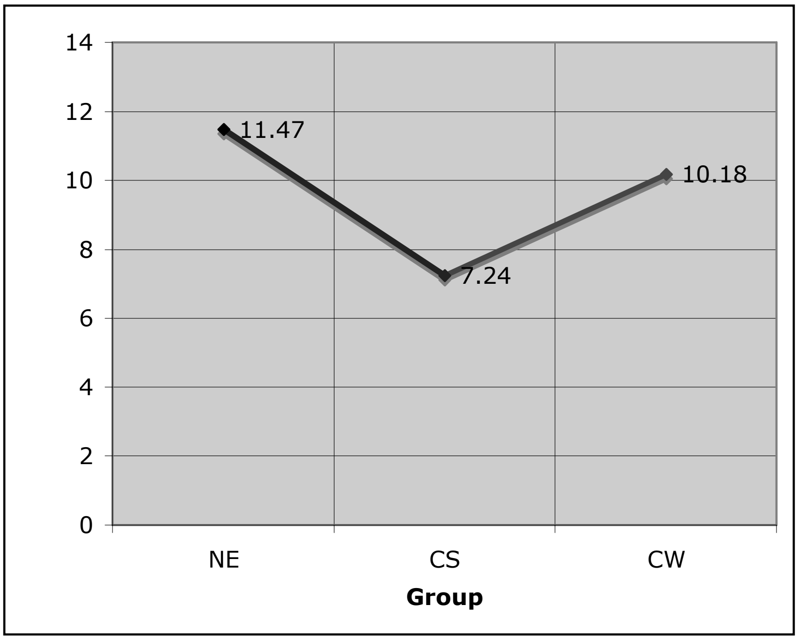

Figure 2. This chart displays the mean transfer activity efficiency by group.

Ability to Detect and Correct Errors

The learners' awareness of their activities during the duplicate task was also affected positively as can be seen in Table 2 in the lower part of the middle column. In this table each of the five categories of possible errors are listed individually along with the number of participants that made that error, whether the participants were able to detect the errors they had made, and whether they were finally able to correct an error. Participants in the NE group that contained the regular instruction without corrected-errors and instruction including explanation and reflection initially made only 40% of possible errors; were able to detect 26.7% of those errors; and were then able to correct 26.7% of those errors; getting 90.7% of the correct by the end of the activity. In contrast participant that where in the CS group and had seen the instruction that contained corrected-errors but did not contain the instructors reflection and explanation initially made 69.3% errors; detected 48% of those errors; and then corrected 46% of those errors and had 65% errors corrected by the end of the transfer activity. Lastly, those in the CW group that contained corrected-errors and the instructors reflection and explanation initially made only 38% of possible errors; detected 34% of those errors; and went on to correct 72.4% of the errors.

Table 2: This table shows a summary of group performance on the transfer task.

	Made	Detected	Corrected
NE	40%	26.7%	26.7%
CS	69.3%	48%	46%
CW	38%	34%	72.4%

Conclusion

The study demonstrates that the inclusion of corrected-errors within asynchronous video based lectures does have an impact on student efficiency indicating the effects that (Skinner, 1968) and (Thorndike, 1927) were afraid of occurring. However, the addition of explicit explanation and reflection after each of the errors led to a negation of those effects. Learners that were in the group that had received access to the instructor meta-cognitive information had almost the same efficiency as those in the control group who had not been exposed to any corrected-errors, as can be see in Figure 2. Moreover, those in the group that had been exposed to corrected-errors had a higher probability of correcting their own errors as can be seen in Table 2. Therefore one can assert that the modeling of corrected-errors in asynchronous video-based lessons leads to an increase in student ability to detect and correct their own errors. The addition of explicit explanation leads to an improvement in efficiency.

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Notational Effects on Use of Collaboratively Constructed Representations During Individual Essay Writing

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Abstract: Prior analyses of collaboration through different notational systems (e.g., threaded discussions and evidence maps) have documented differential influences of notations on collaborative processes as well as ways in which groups appropriate these notations for their work. These prior analyses have focused on collaborative interaction, yet for instrumental purposes in educational practice, the individual is the unit of analysis. Hence it is relevant to ask how individuals use the products of collaborative interaction as documented in a given notational system. This paper reports on an analysis of data from a prior study to uncover how participants went about writing individual essays, drawing on the products of interactionally prior joint problem solving. The analysis first documented parameters of the human-computer interactions through which individual participants accessed and appropriated the record of prior work. Parameters included focus shifts, use of copy/paste, and access to records of data and hypotheses considered. The analysis then compared three experimental conditions and two post-hoc groups on the selected parameters. Profiles plots reveal consistent differences between the use of the notational systems that are indicative of differences in engagement with the materials.

Introduction

Prior work in "representational guidance" tested the hypothesis that conceptual representations can address problems of coherence and convergence that have been shown to be associated with threaded discussions and more effectively support collaborative knowledge construction in online learning (Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2007; Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2008). In that study, participants in an interactionally asynchronous setting were enabled to construct representations of the topics and conclusions of their discussion as they interacted. Two forms of conceptually-enhanced support were compared to each other (Graph vs. Mixed) and to a threaded discussion control condition (Text). After collaborative knowledge construction, participants in the experimental study wrote individual essays with the CSCL environment remaining available and accessible for (re)appropriation. Prior results showed that the three conditions (Text, Graph, and Mixed) did not differ in optimality of conclusions in the essays: relatively few participants in all conditions identified the optimal explanation of the epidemiological facts of the given problem. Pairs in the Graph condition were more likely to converge on the same (not necessarily optimal) conclusion than pairs in the other conditions. The prior analyses tried to explain these observed differences primarily in terms of the influences of the various notations on collaborative interaction.

These analyses did not inquire into the appropriation practices of individuals, that is, how individuals used the persistent inscriptions that resulted from collaborative activity in their subsequent individual meaning-making processes during essay writing. For all practical and instrumental purposes in educational practice, the individual is the unit of analysis. Hence, in general it is appropriate to ask: for an individual, what is the return on collaborative interaction? In everyday life, we document our collaborative interactions and derive personal benefit from such documentation as resources for teaching, reading, writing, and thinking. In the context of this study, we specifically ask: does the notation influence how individuals draw upon the documentation of prior interaction? Are the differences observed in the prior study due the different notations involved? To the particular idiosyncratic and/or systematic ways in which participants used the persistence of interactionally prior collaborative work in writing the essay? Or it is a combination of these two factors?

This paper begins to answer these questions with a human computer interactional (HCI) account of how participants exploit the persistence and perceptibility of a collaboratively constructed knowledge environment by manipulating the interface during essay writing. In order to provide such an account, we first documented interactions such as how frequently focus switching was done, how multiple application windows were managed, how the knowledge-map was navigated, and how informational sources were accessed and appropriated. We then evaluated whether the interactional work done by individuals in writing the essays differed systematically between the three experimental groups and the two post hoc groups of pair convergence and divergence. We present the software environments and method of the prior study before returning to data collection specific to the essay writing analysis.

Methods

The prior study from which our data was derived (Suthers, et al., 2008) used three software environments in order to test hypotheses about the relationship between conceptual representations and collaborative discourse. All three of the environments have an “information viewer” on the left in which materials relevant to the problem are displayed. All three environments have a shared workspace or “information organizer” on the right hand side in which participants can share information they gather from the problem materials as well as their own interpretations and other ideas. The three treatment conditions corresponded to three different notational resources provided for recording and organizing information and participant's interpretations of that information. Participants used one of a threaded discussion environment (the “Text” condition), an evidence mapping environment derived from Belvedere with embedded annotations (“Graph”), or an evidence mapping environment side by side with a threaded discussion and facilities for referential linking between the two (“Mixed”; Figure 1). Changes made to the workspace by each participant are propagated to other participant’s displays of the same workspace under an asynchronous protocol. See (Suthers, et al., 2007; Suthers, et al., 2008) for details of *participants* (30 gender-balanced pairs of participants were recruited from natural science courses), *materials* (information relevant to an epidemiological problem was distributed across participants in a hidden profile design), and *procedures*. The most relevant aspect of the procedures for present purposes is that after participants worked together (via a shared workspace with asynchronous updating) for up to 120 minutes on the epidemiological problem, each individual participant was given up to 30 minutes to write an essay on the hypotheses that were considered, the evidence for and against these hypotheses, and the conclusion reached. The CSCL environment remained available to each participant during the essay writing, but there was no further communication between participants. Table 1 contains the essay writing instructions.

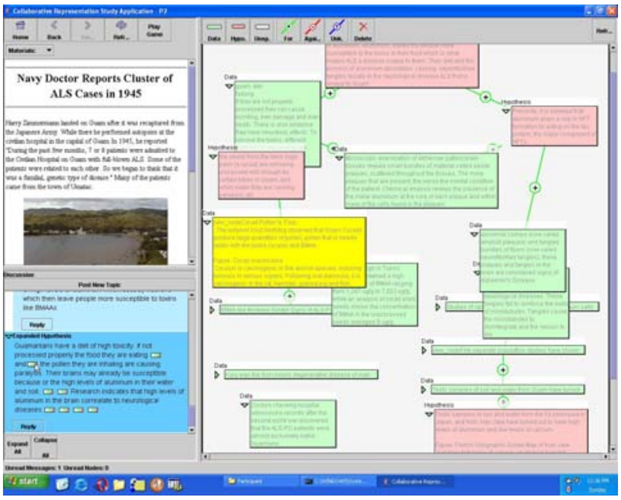

Figure 1. *Mixed* environment

Table 1: Essay Writing Instructions

Instructions. Now that you have completed your exploration of the Guam Science Challenge Problem, please write a short essay (1 – 2 pages) that summarizes your findings. Please structure your essay as follows:

1. For each working hypothesis that you considered, write a brief paragraph describing the hypothesis, and summarizing the evidence for and against it.
2. Write a concluding paragraph in which you identify one or more hypotheses that you believe are best supported by the evidence. Discuss your reasons for choosing that hypothesis or those hypotheses, as well as your reasons for rejecting the other hypotheses you considered.

You will type in your essay into a word processor, using the document that has already been set up for you.
As you write your essay, please keep the following three points in mind:

- We will evaluate your essay based on its content; you don’t need to worry about spelling or formatting.
- Remember to save your document frequently.
- You have up to 30 minutes to write your essay.

Process data was collected through the Morae™ recording software and software logs of all the events at each client workstation. Post-session data included the essay, a usability questionnaire elicited immediately after the experimental session, and a post-test elicited one week later. For the purposes of this paper, we segmented and analyzed the Morae™ screen recordings of the individual essay writing task.

Results

The analysis focused on the (1) total time taken to write the essay, (2) focus shifts between the CSCL environment and the essay application and the essay, (3) note pad window movements, (4) copy+paste instances from the CSCL environment into the essay, (5) accessing individual study materials, accessing elements of the co-constructed knowledge-map such as (6) shared data and (7) shared hypotheses, (8) collaborative discourse, (9) knowledge-map navigation and (10) knowledge-map re-organization. A multivariate analysis of variance with the independent variable of CSCL environment (Graph, Mixed, Text) and the ten dependent variables listed above was significant (Roy's largest root=0.516, F(10, 48)=2.48, p=0.02). However, no significant results were observed with a multivariate analysis of variance with the independent variable of essay pair convergence (convergence and divergence) and the ten dependent variables listed above (Roy's largest root=0.195, F(10, 47)=0.92, p=0.53). Below we describe each univariate measure and the results from univariate analyses of variance, with profile plots for significant results.

Total essay writing time was defined as the time in seconds between the creation of the text editor window and the participant's closing of the editor window. This measure did not differ significantly either between the three experimental conditions or between the two convergence groups. However, average total essay time was higher for Graph as well as for collaborative dyads that converged on their final conclusion in the individually written essays.

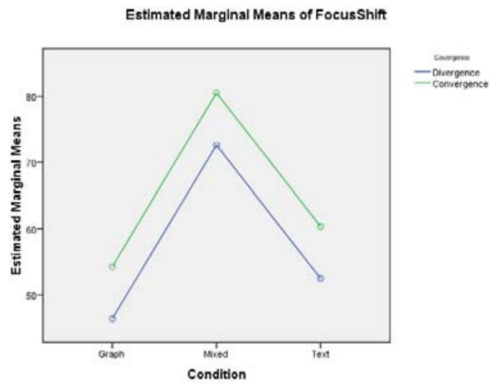

Figure 2. Profile Plot of Focus Shifts

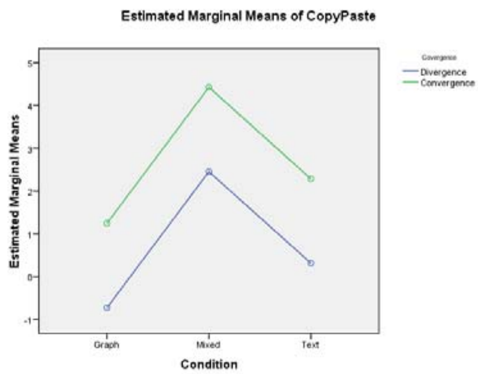

Figure 3. Profile Plot of Copy+Paste

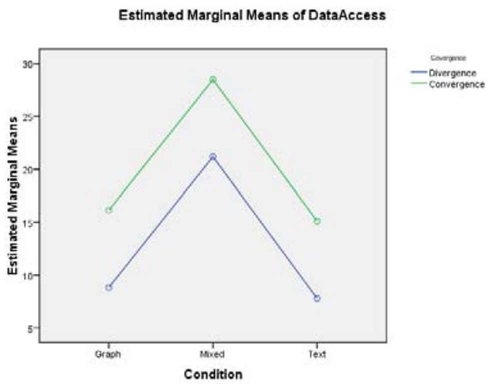

Figure 4. Profile Plot of Shared Data Access

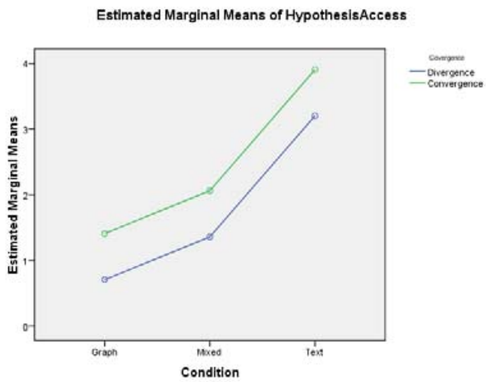

Figure 5. Profile Plot of Shared Hypothesis Access

Due to the single monitor setup of the experimental study, the text editor window was overlaid on the CSCL environment. A *focus shift* resulted when participants switched between the CSCL environment and the text editor by selecting either to be the active window. The total number of focus shifts varied significantly between the three experimental groups ($F(2,56)=3.43$, $p=0.04$). A post-hoc comparison showed that the focus shifts were significantly higher in the Mixed CSCL environment when compared to the Graph environment. No significant differences were observed between the convergent and divergent participant groups. The profile plot for focus shifts is presented in Figure 2.

Since the text editor window was overlaid on the CSCL environment, participants would move the text editor window around the screen in order to make the relevant areas of the CSCL environment perceptible. The total number of *notepad window movements* (or re-positioning) did not vary significantly between the three conditions or the convergence and divergence groups. On average, the text editor window moves were higher in the convergent group and in the Mixed condition than the Text and Graph conditions.

The total number of instances of *copy and paste* of prior text from the CSCL environment into the individual essays was calculated. The number of Copy+Paste instances varied significantly between the three experimental conditions ($F(2,56)=3.17$, $p=0.05$) and was marginally higher for the convergent groups ($F(1,56)=3.50$, $p=0.07$). Figure 3 presents the profile plot.

The study materials were distributed between the two participants in a hidden profile design. Participants needed to not only share the relevant information with their study partner but also collaboratively integrate the distributed and often contradicting information to arrive at the optimal solution to the problem. We counted the number of instances where participants *accessed their uniquely provided study materials* in the "information viewer" window during essay writing. There were no significant differences in access to study materials between the three experimental conditions or the two convergent groups. On average, access to materials was higher for the divergent groups.

We counted instances in which participants *accessed data items* in the shared workspace. This included accessing data nodes as well as data shared in the embedded notes and threaded discussion messages for the Graph and Mixed conditions respectively and data shared as threaded discussion messages in the case of the Text condition. Access to shared data items was significantly different between the three experimental conditions ($F(2,56)=4.18$, $p=0.02$) but not between the convergent and divergent groups (see Figure 4).

Counts were similarly calculated for instances in which participants *accessed hypothesis items* in the shared workspace. This included accessing hypothesis nodes as well as hypotheses stated in the embedded notes and threaded discussion messages in the Graph and Mixed conditions respectively and hypotheses stated in the threaded discussion messages in the case of the Text condition. Hypothesis item access was significantly different between the three experimental conditions ($F(2,56)=4.97$, $p=0.01$) but not between the convergent and divergent groups (see Figure 5).

Counts were calculated for instances in which participants *accessed collaborative discourse* in the shared workspace. This included accessing embedded discussion notes and threaded discussion messages in the Graph and Mixed conditions respectively and threaded discussion messages in the case of the Text condition. There were no significant differences between the three experimental conditions and the two convergent groups.

Counts were obtained for instances when participants *navigated the CSCL environment* by scrolling vertically or horizontally. Scrolling was the mechanism through which participants could access the regions of the CSCL environment that couldn't fit the screen and were therefore hidden from present view. There were no significant differences between the three experimental conditions or the two convergent groups.

Counts were obtained for instances when participants *re-arranged or re-organized the knowledge-map* nodes in the Graph and Mixed conditions and the display of threaded discussion board by collapsing or expanding the tree view in the case of the Text condition. Results showed that marginally significant differences between the three experimental conditions ($F(2,56)=2.54$, $p=0.09$) with no significant differences between the convergent and divergent groups.

Latent semantic analysis (Landauer & Dumais, 1997) was done on the two individually written essays of each collaborative learning session. Pair-wise comparison of each of the two essays of the 30 experimental sessions was conducted within the topic space of High School Biology with 300 Factors and High School Biology with 941 Factors. Thus, we obtained 30 LSA pair-wise agreement values for the 60 individual essays across the 30 sessions (10 each of Mixed, Graph, and Text). A one-way analysis of variance of the LSA pair-wise agreement values was significant within the topic space of High School Biology with 300 Factors ($F(2,27)=6.10$, $p=0.01$) as well as the topic space of High School Biology with 941 Factors $F(2,27)=10.98$, $p=0.0003$). In both cases, post-hoc comparisons showed that pair-wise agreement in the Text condition was significantly higher than Mixed and Graph conditions.

Discussion

A previous analysis (Suthers, et al., 2008) showed greater convergence (pair agreement on the final conclusion) in the Graph condition. This suggested that Graph participants may have shared more information, but our analysis of essay contents did not back up this interpretation: participants in all conditions were equally likely to cite information that was originally given to their partner. Subsequently, we conducted the present analysis of the individual essay writing in order to better understand these results by documenting the human-computer interaction practices by which the essays were composed. The results reveal three empirical trends. The first empirical trend is that for the HCI analysis measures of *focus shifts between the CSCL environment and the text editor* (Figure 1), *text editor window movements*, *number of Copy+Paste instances* (Figure 2), and *access to hypotheses shared in the CSCL environment* (Figure 4), estimated marginal means for the Graph condition were lower than those of Mixed and Text. Frequent focus shifts between the CSCL environment and the text editor window and frequent text editor window movements in the Text and Mixed conditions may induce context switching costs between tasks and ultimately lead to less sustained engagement in either context. Comparatively less number of Copy+Paste instances in the Graph condition might also be indicative of higher re-interpretation of and reflection on prior work. The second empirical trend is that for the measures of *access to data items shared* in the CSCL environment (Figure 3), and *access to study materials* estimated marginal means for the Graph condition were in between those of Mixed and Text. This seems to suggest a point of diminishing returns with regard to individuals' access to shared data artifacts and uniquely provided materials. Due to the "hidden profile" design of the study materials, information uniquely provided to the study partner is accessible to a particular individual participant only if it is shared. The third empirical trend is that for the measures of *total essay writing time* (Figure 4), *access to collaborative discourse in the CSCL environment*, *navigation of the*

CSCL environment, and *CSCL environment organization*, estimated marginal means for the Graph condition were higher than those of Mixed and Text. These four measures can be read as indirect indicators of sustained engagement with the essay writing activity, particularly with respect to the essay instructions provided to each participants (see Table 1). To summarize, the results suggest that participants better exploit the persistence of collaborative knowledge-building and discourse in the Graph condition. As it is to be expected, given the hidden profile distribution of the study materials, higher access to uniquely provided study materials during essay writing is found in the divergent group. In the collaborative phase of the Text condition, participants would usually copy and paste entire study material articles into the shared threaded discussion area. During the individual essay writing activity, Text participants were more likely to access the data items shared in the threaded discussion than the uniquely provided study materials in the "information viewer." This might explain greater latent semantic similarity in the text condition.

We speculate that active navigation and organization of the co-constructed knowledge-map and access to collaborative discourse partially account for the convergence differences. We acknowledge the problematic nature of the casual direction of the explanatory account. Our analysis results provide a tentative answer to the question raised at the beginning of the paper as to whether it is the differential nature of the design of and collaborative knowledge-construction in the Graph condition or the differential essay compositional strategies and human-computer interactional practices that better explain the differential essay convergence outcomes. The analysis of essay writing sheds some light on the human-computer interactional practices of the actual essay composition. The HCI measures introduced in this paper help provide a partial explanation for the between-group differences in individual learning outcomes with respect to the essays, supplementing the traditional explanations that attribute the between-group differences to investigative session alone (Cf. Ruben, 1990 for the distinction between partial and full explanations and the distinction between processes and products of explanation).

The HCI analysis reported here applies a variable-based approach to categorizing and aggregating individual interactional acts in order to investigate the relative distribution of pedagogically interesting behavior, in contrast to sequential analysis (e.g., Medina, Suthers, & Vatrapu, 2009). The analytical focus was on "usage" rather than the formal properties of interactional structures and functions. This analytical goal was to operationalize, in an experimental setting, traditional interaction analysis concerns with participants' perceptual orientation and allocation of attentional resources from a HCI perspective. In light of the recent methodological discussions within the CSCL community, our analysis adopts and advocates a modestly mixed research approach and introduces some HCI measures for CSCL analysis.

Even though co-constructed collaborative knowledge is expressed in the persistent digital medium, it might not be readily accessible and available for re-appropriation by individuals. The question then is: How easy or difficult do different CSCL environments make it for individuals or small groups to return to the environment to reap the benefits of prior collaborative achievements and interactional accomplishments? Are there tradeoffs in designing and implementing CSCL environments for real-time collaborative interaction versus the individual learner returning to a partial or complete interactional archive any-time re-appropriation? According to Pirolli and Card (1999, p. 643), "Information Foraging Theory is an approach to understanding how strategies and technologies for information seeking, gathering, and consumption are adapted to the flux of information in the environment." In CSCL environments, to what extent does information foraging differ between individual and collaborative modes of interaction? These remain empirical questions for future CSCL research.

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PART II

CSCL PRACTICES IN EDUCATIONAL SETTINGS

How Gender Composition influences Individual Knowledge Elaboration in CSCL

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Abstract: The aim of the study is to explore the gender difference in learning achievement and knowledge elaboration process in CSCL. A sample of ninety-six secondary school students, aged 16, participated in the two-week experiment. Students were randomly paired to solve six problems about Newtonian mechanics. Their pre- and post-test performances and online interactions were analyzed. We found that female students' learning performance and knowledge elaboration process were sensitive to their partner gender, but that's not the case for male students. Besides, due to a divergent knowledge elaboration process, mixed-gender dyads run the risk of disadvantaging female students in CSCL.

Introduction

To date, there is very little research looking into the gender difference of knowledge elaboration process in Computer-Based Collaborative Learning (CSCL). Questions such as whether, in CSCL, female and male students benefit equally from the mixed- and single-gender dyads, whether the knowledge elaboration in mixed-gender dyads presents a different picture in comparison with that in single-gender dyads, and how students' learning performance is related with the knowledge elaboration process still need empirical investigation. We start with a discussion on the properties of CSCL that may play a role in students' knowledge elaboration in collaboration.

Knowledge Elaboration in CSCL

The text-based Computer-Mediated Communication (CMC) is dominantly applied in CSCL practices. It affords the opportunity of a well-balanced knowledge elaboration. Students' interactions are preserved in a shared context, which seems to be privileged to deepen their thinking and trigger a high level elaboration. The explicit back-references may facilitate more thoughtful and reflective discussions as well. However, the reduced shared context is also expected to have reduced utility (Suthers, 2006). In addition, due to the ease of typing and exchanging messages, synchronous CSCL may generate numerous fragmented and incoherent interactions. The breakdown in interaction may exacerbate the potential problem in mixed-gender collaboration.

Making inferences to students' external representations during problem solving may unravel the process of students' cognitive elaborations (DeWindt-King & Goldin, 2003). Kumpulainen and Mutanen (1999) differentiate three cognitive processing modes. The *off-task activity* refers to the social talk that is irrelevant to collaborative task. The *procedural processing* refers to the routine execution of task without improving the ideas. The *interpretative or exploratory processing* refers to students' deep engagement in problem solving activity, which is characterized by critical thinking and a systematic analysis of problem information. Based on that, Ding (2008) endows each message with an elaboration value: -1 (off-task), 0 (procedural) or +1(interpretative), and plots the sums of the values for each individual learner along the timeline. Such kind of visualization has revealed, at least, three patterns of knowledge elaboration process. The *divergent pattern* (on the left in Figure 1) is featured by two diverging curves. It shows an increasing cognitive discrepancy between two participants. The *cross pattern* (in the middle in Figure 1) illustrates that individual knowledge elaboration processes are closely intertwined. The participants keep a close eye on their partner's processing and take turns dominating the knowledge elaboration. The *parallel pattern* (on the right in Figure 1) indicates that the cognitive gap between the two participants keeps the same during collaboration. With the help of the patterns, we are motivated to investigate whether there is a difference between mixed-gender and single-gender dyads with regard to the knowledge elaboration process, and whether students' learning achievement is affected by it.

Materials and Methods

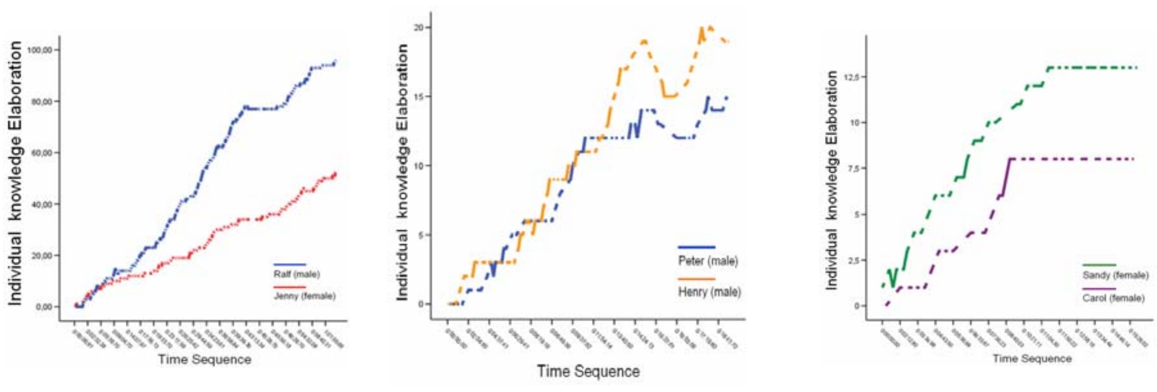
Research Questions:

The research questions of the study were, in CSCL,

- → is there a gender difference in learning achievement?
- → is there a difference in knowledge elaboration process between mixed- and single-gender dyads
- → is there an interaction effect of group gender and knowledge elaboration, on students' learning achievement?

Participants

The study was conducted in a secondary school in Shanghai, China. Ninety-six students, aged 16 from two classes of grade ten, participated in the two-week experiment. There were 49 females and 47 males. Students come from families with various social backgrounds. During the experiment, they were randomly paired within the class. There were three groups according to gender: group of mixed-gender dyads (MG, n=25), group of female-female dyads (FF, n=12), and group of male-male dyads (MM, n=11). Students were categorized into four conditions: female in mixed-gender dyads (F in MG, n=25), male in mixed-gender dyads (M in MG, n=25), female in female-female dyads (F in FF, n=24), and male in male-male dyads (M in MM, n=22).



divergent pattern cross pattern parallel pattern

Figure 1. Knowledge Elaboration Patterns.

PhysHint

The computer program “PhysHint” designed by the author was compiled with SQL to facilitate a synchronous online collaboration. There are five sections in the PhysHint interface. The *problem section* shows the problem information. The problem could not been read until both partners logged into the system. During the experiment, six physics problems in the database were used. The *hints section* offered each student five “hints” for each problem. To strengthen their communication, different students within the same dyad received different hints. In the *drawing section*, students were able to draw the variables and vectors using geometric forms, arrows and lines. Their drawings would be automatically shown on his/her partner’s computer. The *chatting section* resembled the online Messenger that students were familiar with. For each problem students had two chances to try their answer. At the second time they failed, a window with the “*worked-out example*” popped up.

Procedure

All participants followed three regular lessons concerning Newton’s second law taught by the same physics teacher. Students were administered a 40-minute long pretest concerning Newton’s second law. After that, they were given a preflight training about how to use the online program “Physhint”. The experiment included six 40-minute long sessions. In each session, students were asked to solve one problem. On the last day, all students participated in a 40-minute long posttest. Both pre and posttests was paper-pencil test. Each consisted of four moderately-structured problems. The same as the problems in experiment sessions, test problems were selected from the database with the similar degree of difficulty. Students were required to solve them independently.

Data Collection and Analyses

Students’ online messages were collected and analyzed through the “elaboration values” (see Table 1).

Table 1: Elaboration Values

Number	Description	Example
+1	on-task message elaborating on knowledge or contributing to the final solution.	*Student A: How many forces applied on the box?* *Student B: I think, four*
0	on-task message but no improvement of knowledge elaboration or problem solving	*(Student B: There are four forces applied on the box.)* *Student A: OK.*
-1	off-task messages distracting the problem solving process	*Student B: Guess, what will be in our next English test?*

There are two points that should be pointed out. Firstly, we acknowledged the importance of elaborative questions. Our previous finding indicated that female and male students had different communication styles (Ding & Harskamp, 2006). In collaborative problem solving, female students tended to use question to start the discussion or express opinions. An elaborative question not only kept the collaboration on the right track, but fostered partner's knowledge elaboration. Therefore, not only interpretative or exploratory processing would be endowed +1 point, but also the elaborative questions. Secondly, CSCL is characterized by a large amount of in-coherences in interactions, sometimes even "messy" talks. So, when we evaluated each individual message, we did not merely relate it to the previous one message, but to the whole context. In order to analyze students' online interaction, five independent coders were trained. All were sophomores majoring mechanics. They were instructed about how to code through the "Elaboration Value" system. We selected the data of all six problems. Due to the huge amount of data, each coder spent more than 20 hours on coding. The interrater reliability calculated by a Pearson product-moment correlation is 0.74.

Results

The individual knowledge elaboration process varies stochastically across dyads. Research methodology should be adequate for identifying these effects (Cress, 2008). Therefore, we used multilevel analyses to answer our research questions. A two level modeling with individual student at level 1 and the dyad at level 2 was constructed. The dependent variable was the students' posttest scores, and the gender, group gender and elaboration patterns were the explanatory variables. Table 2 presents the results of the multilevel analyses with estimation for individual posttest scores. We first established an empty model without any independent variables (Snijders & Bosker, 1999). It showed that a large part (127.92/(127.90+66.88)=0.66) of the total variance in students' posttest scores may be attributed to difference on group level, that is, the group gender and the knowledge elaboration patterns. Then, we added explanatory variables to the model.

In Model 1 and 2, we added the *gender* and *group gender*, respectively. In Model 1, the males were the reference group, and in Model 2 the mixed-gender dyads were the reference group. The reduction of deviance suggested that very little of the differences between students was explained by their gender (deviance=751.41, χ^2=.04, p>.05) or group (deviance=751.26, χ^2=.15, p>.05). Then, we focused on four conditions. Condition *F in MG* was the only condition that scored significantly lower than the other three conditions, namely, M in MG, F in FF and M in MM (deviance=745.61, χ^2=5.65, p<.05). To explore the reason and examine whether the low performance of females in mixed-gender dyads was related with the different knowledge elaboration patterns, we added *Divergent Patterns* as an explanatory variable in Model 4. The reduction of deviance was highly significant (deviance=693.90, χ^2=51.71, p<.05). It indicated that those who were involved in the divergent patterns scored 7.21 lower than those who engaged in cross and parallel patterns. The effect of divergent patterns was significant (t=-9.61, p<.05). But the effect of cross or parallel patterns was not significant.

The ANOVA test showed that there were significantly more divergent patterns in the mixed-gender dyads than that in the single-gender dyads $F_{(2,95)}$=3.40, p<.05. Now, two questions arose. First, has the divergent pattern particularly disadvantaged female students? Second, has the divergent pattern only disadvantaged students in the mixed-gender dyads? We constructed Model 5 and 6 to explore the interaction effect of gender or group gender and divergent patterns. The reduction of deviance of Model 5 was not significant (deviance=690.65, χ^2=3.25, p>.05). Yet, Model 6 showed a significant interaction effect of the group gender and the divergent pattern on students' posttest performance (deviance=682.83, χ^2=7.83, p<.05). In mixed-gender dyads, the more divergent patterns, the lower students scored in the posttest.

In order to explore whether divergent patterns could explain the disadvantage of females in mixed-gender dyads, we constructed Model 7. In this model, we looked into the interaction effect of students' *gender*, *group gender* and the frequency of *divergent patterns*. The results showed a significant reduction of deviance in comparison with Model 6 (deviance=975.90, χ^2=6.93, p<.05). For F in MG, the involvement of divergent patterns resulted that they scored 7.08 lower than other students in the posttest. In other words, the more divergent patterns in the mixed-gender dyads, the lower female students scored in the posttest.

Conclusion and Discussion

The study was conducted in a synchronous CSCL setting that was designed to facilitate physics problem solving. Because students' learning achievement on the posttest was at the individual level while the knowledge elaboration patterns were formed at the group level, we resorted to the multilevel analyses to explicate the relationship between students' gender, group gender, knowledge elaboration process and learning achievement. It was found that in the mixed-gender dyads, the low performance of female students in the posttest may attribute to the frequency of divergent patterns. The more divergent patterns, the lower scores females in the mixed-gender dyads achieved.

A "close-up" view of one mixed-gender dyad's interaction log files uncovered several possible factors that resulted in the divergent patterns. Firstly, the male tended to use visual representation to answer his female partners' questions instead of verbal explanations. By contrast, the female student tended to use text-based messages. The different ways of knowledge representation may impede the female's knowledge elaboration. Second, due to the CSCL properties, students' messages were in simple and incoherent form, and students worked on the problem in different tempo due to the lack of shared context. When the female student was still stuck on the force analysis, the male student has already started calculation. Thirdly, when the female complained that her partner moved too fast, the male ignored her words and continued with his calculation. The female also gave up her question and accepted the male's answer. The male's *no-explanation* and the female's *giving-up-asking* led to a divergent elaboration pattern. This finding potentially taps into the investigation regarding why female students performed worse in mixed-gender dyads than in single-gender dyads in physics collaborative learning.

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Table 2: Summary of the model estimates for the two-level analyses of students' post-test scores.

Parameter	Model							
	0	**1**	**2**	**3**	**4**	**5**	6	7
Fixed								
Intercept	72.65 (1.83)	72.41 (2.12)	73.132 (2.86)	84.97 (2.80)	84.99 (2.80)	88.13 (3.13)	81.59 (3.77)	88.36 (4.37)
Gender		0.46 (2.13)	0.456 (2.12)	10.81 (2.93)	10.81 (2.93)*	4.91 (4.17)	5.14 (3.99)	-6.56 (5.74)
Group Gender			-1.380 (3.70)	10.64 (2.83)	10.37 (2.83)*	11.22 (2.75)*	22.02 (4.50)*	11.80 (5.73)*
Female in MG vs. others				-13.41 (5.52)*	-12.53 (3.72)*	-14.31 (3.75)*	-14.67 (3.60)*	3.93 (7.76)
Divergent					-7.21 (0.75)*	-8.50 (0.98)*	-5.83 (1.34)*	-8.59 (1.63)*
Female * Divergent						2.46 (1.30)	2.50 (1.27)	7.37 (2.17)*
Groups * Divergent							-4.03 (1.39)*	-0.16 (1.95)
Female * Groups * Divergent								-7.08 (2.64)*
Variance								
Group Level	127.90 (33.63)	126,39 (33.38)	125.93 (33.28)	111.47(30.26)	16.16 (12.10)	9.64 (11.43)	2.89 (10.39)	0.82 (9.65)
Individual Level	66.88 (13.65)	67.34 (13.75)	67.34 (13.75)	66.11(13.49)	66.10 (13.49)	68.93 (14.07)	69.04 (14.09)	66.05 (13.48)
Deviance **(-2 Logliklihood)**	751.45	751.41	751.26	745.61	693.90	690.65	682.83	675.90
Decrease in Deviance		0.04	0.15	5.65*	51.71*	3.25	7.83*	6.93*

*$p<.05$

Procedural and Conceptual Knowledge Acquisition in Mathematics: Where is Collaboration Helpful?

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Abstract: While research has generally shown that collaboration may facilitate student learning in mathematics, such positive effects are not always found. We argue that the effectiveness of collaboration may depend on the type of knowledge the instruction targets: The interaction with a partner can slow down students and may thus decrease the amount of practice necessary for *procedural skill fluency.* On the other hand, collaboration could be particularly useful for *conceptual knowledge acquisition,* as here, the elaborative meaning-making activities ascribed to collaboration may facilitate learning. To evaluate the differential effects of collaborative learning, we compared four conditions: individual versus collaborative learning with procedural instruction, and individual versus collaborative learning with conceptual instruction. The study results support our hypotheses: Students who learned individually showed higher test scores in a procedural far transfer test. However, a combination test requiring both knowledge types revealed a positive impact of collaboration on students' conceptual knowledge acquisition.

Introduction

Collaborative learning environments have generally shown to be beneficial for learning in mathematics (e.g. Berg, 1994; Ellis, Klahr & Siegler, 1993). The positive effect of collaboration can be explained by particular student interactions such as giving explanations and knowledge co-construction that are positively related to learning (e.g. Hausmann, Chi, & Roy, 2004). However, this beneficial impact of collaboration on learning is not always found (e.g. Dillenbourg, Baker, Blaye & O'Malley, 1996; Lou et al., 1996; Souvignier & Kronenberger, 2007). The meta analysis on collaborative learning by Lou et al. (1996) gives a good overview of this phenomenon: Although most results were in favor of collaborative learning, about a fourth of the results showed negative effects. Also in one of our own projects, comparing individual to collaborative learning with the Cognitive Tutor Algebra, results were inconsistent (Rummel, Diziol, & Spada, 2008): We found no differences between conditions in a retention test that mainly required *procedural knowledge* (e.g. computational skills). Observations of students' problem-solving process indicated that collaboration might even have impeded the acquisition of this knowledge type as the interaction with the partner slowed the students down and thus decreased the amount of practice. On the other hand, we found indications that the interaction with a peer improved students' understanding of the underlying mathematical concepts, i.e., *their conceptual knowledge*. The advantage of collaboration was particularly found when students engaged in mutual explanations and deep discussions of the learning content (Diziol & Rummel, 2008). These results led us to the conclusion that the inconsistency in collaborative learning research may in part be explained by differential effects of collaboration on procedural and conceptual knowledge acquisition. In other words the benefits of collaboration on student learning may depend on the type of task solved collaboratively and on the type of knowledge students are expected to acquire during the interaction. The aim of the study presented in this paper is to increase our knowledge of these differential effects of collaboration on student learning in mathematics. This knowledge can help to introduce collaborative learning more selectively within the school classroom.In the following sections, we will give a short overview on the differentiation between procedural and conceptual knowledge acquisition in mathematics. Then we will discuss results on collaborative learning regarding this differentiation. We will conclude the theoretical background with a short overview on our study hypotheses.

Procedural and Conceptual Knowledge Acquisition in Mathematics

Literature on knowledge acquisition in mathematics distinguishes between two different types of knowledge: procedural and conceptual knowledge. *Procedural knowledge* refers to students' ability to execute action sequences in order to solve routine problems (e.g. Rittle-Johnson & Alibali, 1999). Students learn step-by-step solution procedures and, by repeatedly solving tasks that require these procedures, their proficiency improves. A typical example for tasks that requires procedural knowledge are manipulation problems such as solving equations for x (Nathan, Mertz & Ryan, 1994). If students know the relevant procedures, they can easily solve the task. However, procedural knowledge is closely tied to specific problem types and thus is not widely generalizable.

In contrast, conceptual knowledge is rather flexible and thus enables students to solve problems that are based on the same mathematical principles, but have a different problem format. The ability to transfer knowledge to new problems is considered an important step in gaining mathematical literacy as it enables students to apply their mathematical knowledge in everyday life (OEDC, 2003). Conceptual knowledge is the understanding "of the principles that govern a domain and of the interrelations between pieces of knowledge in a domain" (Rittle-Johnson & Alibali, 1999, p. 175). For instance, in the domain of algebra, particularly relevant concepts are the equation, the variable, and the constant term. These concepts can be represented in different formats, for instance, verbally in a story problem ("they earn \$2 per glass sold"), graphically in a coordinate plane, algebraically in an equation ("+ 2*x*"), or in a table (cf. Brenner et al., 1997). If students show the ability to flexibly translate between the different representations, this indicates that they have developed a solid understanding of the underlying algebraic concepts (Brenner et al., 1997; Mevarech & Stern, 1997).

Often, it is not possible to clearly distinguish between procedural and conceptual knowledge (cf. Hiebert & Wearne, 1996). Rittle-Johnson, Siegler and Alibali (2001) therefore describe the relation between procedural and conceptual knowledge as a continuum with procedural and conceptual knowledge as its two ends. According to their model, procedural and conceptual knowledge acquisition influence each other in an iterative way, in other words, improvement in one knowledge type can result in improvement in the second type of knowledge. A high understanding of underlying concepts can help to monitor the appropriateness of procedures and their correct execution, thus conceptual knowledge can influence the performance of procedural tasks. For instance in the domain of algebra, a good understanding of the concept "variable" can help to prevent a student from trying to add a constant and a variable term, a procedural error that is quite typical in students' problem-solving (see Booth, Koedinger, & Siegler, 2007). Conceptual knowledge can also improve when students solve procedural tasks, as long as they engage in active learning processes and try to understand the underlying principles.

To make predictions about the effectiveness of collaboration in supporting the acquisition of these two knowledge types, we need to take a closer look at the processes that yield procedural and conceptual learning. For procedural knowledge acquisition, students first have to be introduced to the procedures that are relevant to solve a particular task type. Then, to gain procedural skill fluency, practicing the application of the procedures is most crucial. One method that has shown particularly effective in improving students' procedural knowledge is guidance by an intelligent tutoring system (Koedinger, 1998). Intelligent tutoring systems monitor the student's progress, provide immediate error feedback and give help upon request that is tailored to the student's needs. The immediacy of feedback has proven particularly conducive to student's learning since it yields substantial cognitive and motivational benefits (Koedinger, 1998). For conceptual knowledge acquisition, merely solving problems is not sufficient (Hiebert & Wearne, 1996). Rather, students have to engage in active learning processes in order to gain an understanding of the domain principles, that is, they have to elaborate on the learning content to increase their understanding. For instance, these elaboration processes are required when solving algebra story problems, that is, when students have to translate between the verbal problem description and an algebraic equation. Simple translation rules based on keywords might not always yield the correct solution (cf. Nathan, Kintsch, & Young, 1992; e.g., "the depth *increases* by 3 m per hour" might have to be translated to "-3 *x*", even though the word "increase" normally might infer a positive variable term). Instead, students have to correctly represent the problem scenario described, extract the important information, and transform this information into a different, that is, a mathematical representation format (Staub & Reusser, 1995). Through elaboration on these representation translations, students can increase their understanding of the underlying mathematical concepts.

The Influence of Collaboration on Knowledge Acquisition in Mathematics

So far, research on collaborative learning does not support conclusions on the differential influence of collaboration on procedural and conceptual knowledge acquisition. First, the two knowledge types were often confused in the instruction. For instance, Berg (1994) compared individual and collaborative learning in mathematics over the course of several weeks. In the collaborative condition, student problem-solving was supported by a collaboration script. The script prompted students to engage in mutual explanation, i.e. deep cognitive processes, during problem-solving. Post-test comparisons showed that students who learned collaboratively outperformed the individual learners. Similar results were found in a study by Ellis et al. (1993) where students learned to solve decimal fraction tasks either individually or together with a partner. As in Berg's study, the collaborative learning process was supported by a script that encouraged students to give explanations. In a first step, students were asked to compare two decimal fractions individually and to decide which number they deemed to be larger. Next, they joined with their partner, discussed their individual decisions, agreed upon one solution, and received feedback on the correctness of their solution. Again, students in the collaborative condition outperformed individual learners. In both studies, the instruction targeted both knowledge types: Students were instructed to collaboratively solve problems – thereby training their procedural skills; additionally they received instructions that prompted them to collaboratively engage in deep reasoning processes – thereby fostering their conceptual knowledge. This confusion yields the following question: Does the collaborative application of problem-solving procedures itself have an effect, or is the effect mediated by joint elaboration on the underlying mathematical background? In other words, is collaborative practice in applying *procedures* effective, or is it the collaborative elaboration of mathematical *concepts* that yields differences in learning outcome? Second, additional instructions that foster conceptual knowledge acquisition are often only given to the collaborative conditions. Also in Berg (1994) and Ellis et al. (1993), students that learned individually were not encouraged to self-explain their solutions and to elaborate on their thinking, while the instructions of the collaborative conditions encouraged students to engage in deep learning processes. Indeed, positive results of collaboration can particularly be found if collaborative conditions receive additional instructions that are not given to students learning individually (cf. meta-analysis of Lou et al., 1996). This yields the question whether the effectiveness of collaboration is due to the collaboration per se or due to the additional instruction. Finally, another area of confusion concerns the tasks used for assessing the learning effect. Either the tasks that assessed student learning required both procedural and conceptual knowledge, or information on the test material was not sufficient to judge which knowledge type was improved. Thus, it is not clear if the collaboration positively influenced students' procedural performance or their conceptual knowledge acquisition.

In this project, we aim to evaluate the differential effect of collaboration on the two knowledge types. We argue that the learning mechanisms ascribed to collaboration might be particularly beneficial for conceptual knowledge acquisition, while for procedural knowledge acquisition, collaborative learning might not be beneficial or might even have a detrimental effect when compared to individual learning. As discussed earlier, in order to gain mastery in procedural skills, students have to practice the application of procedures. However, several studies have found that collaboration often takes more time than individual problem-solving as further requirements such as coordinating the interaction are added (e.g., Lou, Abrami, & d'Apollonia, 2001; Rummel et al., 2008; Walker, Rummel, & Koedinger, 2008). If the interaction with a partner slows the student down, this might decrease the amount of practice necessary for procedural skill fluency. Additionally, students have to "share" the practice opportunities with their partner, further reducing the amount of practice available for the individual student. This might result in a negative effect of collaborative problem-solving on procedural knowledge acquisition. In contrast, in order to gain conceptual understanding, it is necessary that students elaborate on mathematical concepts and try to understand their meaning. Thus, for conceptual knowledge acquisition, the elaborative meaning-making activities ascribed to collaboration may serve to support student learning. First, in a collaborative setting, students are required to make their thinking explicit and verbalize their knowledge. In other words, they have to give explanations to their partners (cf. Hausmann et al., 2004; Webb, 1989). Often they have to reformulate and clarify their statements if their partner has difficulties in understanding their explanations. This verbalization and reformulation of knowledge demands elaboration on the learning content (O'Donnell, 1999) and thus might be beneficial for conceptual knowledge acquisition. Furthermore, research has shown that students can acquire a deeper conceptual understanding by jointly elaborating on the learning material in order to construct new knowledge. Particularly in the domain of mathematics, knowledge co-construction has been shown to yield improved student achievement (e.g. Berg, 1994). Finally, by asking for help and receiving explanations from a partner (e.g., Webb, 1989), the interaction with a partner enables the student to fill knowledge gaps and correct misconceptions. While these learning processes are less important for the acquisition of procedural skill fluency, for the acquisition of conceptual knowledge, the interaction with a learning partner can foster elaborative processes and thus improve conceptual knowledge acquisition when compared to individual learning.

To assess the differential effect of collaboration on both knowledge types, we compared four conditions: individual versus collaborative learning with procedural instruction (problem-solving practice), and individual versus collaborative learning with conceptual instruction (elaboration on mathematical concepts). We assessed the effect of the four conditions both on procedural and conceptual knowledge acquisition. First, we hypothesized that the procedural instruction would mainly yield benefits on students' procedural knowledge acquisition, and that the conceptual instruction would mainly yield benefits on students' conceptual knowledge acquisition. Second, we hypothesized that regarding procedural knowledge acquisition, individual learning with procedural instruction would outperform collaborative learning with procedural instruction, while regarding conceptual knowledge acquisition, collaborative learning with conceptual instruction would outperform individual learning with conceptual instruction.

Methods

Study Design and Procedure

As was mentioned above, we compared the following four conditions: individual versus collaborative learning with procedural instruction, and individual versus collaborative learning with conceptual instruction (see Table 1). The study was an initial small scale study to establish basic effects. The study procedure consisted of three phases: a pre-test phase, a learning phase, and a post-test phase. In the pre-test, students individually solved procedural and conceptual problems to assess their prior knowledge. The tests were conducted using paper and pencil. During the learning phase, students solved problems in a tutored learning environment on the computer according to their condition. In the collaborative conditions, two students worked together on one computer to solve the task (i.e. face-to-face interaction). While students worked on the problems, they received immediate feedback concerning the correctness of their problem-solving. The system automatically logged students' problem-solving actions, and their interaction was video-recorded. After the learning phase, students took a post-test that consisted of five problem-sets: near and far transfer items for each knowledge type and a combination problem-set. The order of the procedural and the conceptual problem sets in pre- and post-test was counterbalanced across conditions. As in the pre-test, the post-test was conducted individually using paper and pencil. Students could solve the problems in their own pace both during pre- and post-test and during instruction. The pre-test phase lasted for approximately 15 minutes, the learning phase took approximately 50 minutes, and the five problem sets of the post-test phase took approximately another 50 minutes in total.

Table 1: Study Design and Procedure

	Procedural conditions		Conceptual conditions	
	Individual	Collaborative	Individual	Collaborative
Pre-test phase	individual problem-solving (paper-pencil) order of procedural and conceptual problem-set counterbalanced across conditions			
Learning phase	individually or in dyads: procedural instruction (tutored learning environment)		individually or in dyads: conceptual instruction (tutored learning environment)	
Post-test phase	individual problem-solving (paper-pencil) procedural and conceptual near and far transfer problem-sets (order counterbalanced across conditions) combination problem set			

Material

Instruction During the Learning Phase

The task domain of the study was linear algebra. During the learning phase, students were instructed to solve problems on the computer. The learning environment was developed with the Cognitive Tutor Authoring Tool (CTAT, Aleven McLaren, Sewall, & Koedinger, in press), a software tool developed at the Carnegie Mellon University (CMU), Pittsburgh, that enables researchers and teachers to author intelligent tutoring behavior. In its functionality, it resembles the intelligent tutoring systems described in the introduction; however, it does not require the same amount of time and expertise for developing and adding new tasks. Students received immediate feedback to their actions: errors were marked in red, and correct answers were marked in green. Furthermore, when students made an error, they received a hint that prompted them to reflect on the error in order to find the correct answer (see Figure 1a). Within the procedural and the conceptual conditions, respectively, students working individually and students working collaboratively received the same hints. We wanted to ensure that individual and collaborative conditions received the same amount and type of support. The procedural and conceptual conditions differed in the following way: In the *procedural instruction conditions*, students were asked to solve linear equations (see Figure 1a). The problems had increasing difficulty, reaching from simple equations with one variable and one constant term to equations with several variable terms (e.g. $8x + 5 + 6x = 12$), negative constant and variable terms, and subtraction and multiplication brackets. The total number of problems to solve was 29. In the *conceptual instruction conditions*, students were presented with a linear equation and three story problems (see Figure 1b). For each story problem, they judged the validity of the linear equation to represent the story problem (i.e. "true" or "false"). The errors inserted in the story problems were based on several typical misconceptions of students: for instance, the constant term and the coefficient of the variable term were mixed up, the algebraic signs were incorrect, or the brackets were set in a wrong way. Also some of the correct story problems contained "decoys" that typically yield difficulties in student problem-solving such as irrelevant numeric information or additional conversions that had to be accomplished to solve the task (for instance, convert percent numbers in decimal numbers). For each type of misconception and for each type of decoy, we constructed three story problems. In total, students solved nine problems with one equation and three story problems each. The number of problems to be solved during the learning phase was based on previous test runs in order to keep the time constant between conditions. In all four conditions students could only proceed to the next problem once they had solved a given problem correctly.

We compared conditions based on one outcome and two process variables. The *error rate* measures the relative number of errors on the first attempt. An error rate of 1 indicates that students solved each step incorrectly; an error rate of 0 indicates that students solved each step correctly on the first attempt. As process variables, we extracted the average *time spent prior to an action*, and the average *time spent following an error*. These variables can serve as indicators for cognitive processes in problem-solving (cf. Rummel et al, 2008).

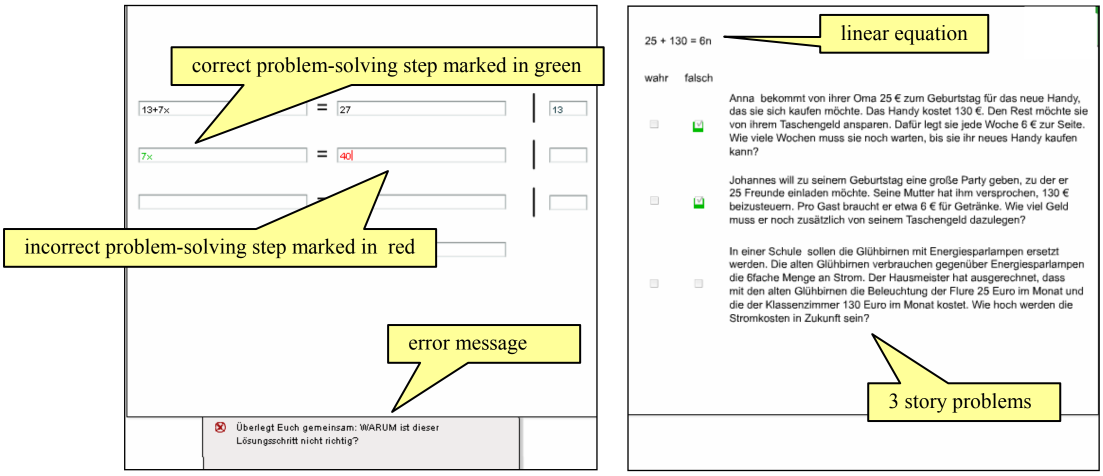

Figure 1: Screenshot of the tutorial learning environments (in German): a) procedural instruction (solving equations) b) conceptual instruction (judging the correspondence of story problems and equations).

Test Material

Both the pre-test and the post-test were solved on paper. Students worked individually without receiving feedback on their problem-solving. The *pre-test* consisted of a *procedural problem set* with eight problems and a *conceptual problem set* with two problems (i.e. two equations with three story problems each). The problems of the pre-test had a lower difficulty level than the problems of the learning phase, but were structurally equivalent.

The post-test consisted of five problem sets: procedural near transfer and procedural far transfer, conceptual near transfer and conceptual far transfer, and combination problems. The *near transfer problems* were structurally equivalent to the problems of the learning phase (12 procedural problems, 3 conceptual problems). In the *far transfer problems*, students were asked to find errors in the solution of a fictitious student and correct them (4 errors in the procedural, 3 errors in the conceptual problems). In the procedural far transfer set, the fictitious student had made several typical computational errors such as combining constant and variable terms when solving equations for the variable. In the conceptual far transfer set, the fictitious student had derived equations from story problems; some of these equations were erroneous, for instance confusing the coefficient with the constant term. Finally, the *combination problems* assessed both knowledge types: In a first step that required conceptual knowledge, students derived an equation corresponding to a story problem; in a second step that required procedural knowledge, they solved the equation for *x*. In total, students solved three combination problems. For the pre-test and the near transfer problems of the post-test, we analyzed the total number of *problems solved correctly*. For the far transfer problems, we extracted two variables: the amount of *errors detected* and the amount of *errors corrected*. Finally, in the combination problems, we evaluated both the amount of *equations that were derived correctly* (conceptual problem-solving step) and the number of *combination problems that were solved correctly* (i.e. students had solved correctly both the conceptual and the procedural problem-solving step).

Participants

Thirty students participated in the study: five students per individual condition and five dyads per collaborative condition. The participants had been recruited from a local high school (Realschule). They were in grade 8 and already had basic experience with solving equations and story-problems. We randomly assigned students to conditions. In the collaborative conditions, students were allowed to choose one of their class mates as their collaboration partner. Most students chose a partner with a similar prior knowledge, thus worked in homogenous dyads. Seventeen students were male, thirteen students were female. Their mean age was 13.77 (.52) years. Conditions did not differ with regard to their prior knowledge assessed as their grade in mathematics and the scores received in the pre-test. In the procedural pre-test, students solved 4.60 out of 8 tasks correctly; in the conceptual pre-test, students solved 3.37 out of 6 tasks correctly.

Results

We compared student behavior during the learning phase, and their individual learning outcomes (for means and standard deviations, see Table 2). Due to the small study sample, we chose an α-level of .10. The differences in the instructional material presented to students in the procedural and the conceptual conditions during the *learning phase* do not allow for direct comparison of student performance across all four conditions. Therefore, for this phase, we compared individual and collaborative performance (error rate) in the procedural conditions, and individual and collaborative performance in the conceptual conditions separately, using ANCOVA analysis (covariate: prior knowledge as assessed in the pre-test). For the *post-tests*, we compared all four conditions with a two-factorial covariance analysis with instruction (procedural vs. conceptual) as factor 1, learning situation (individual vs. collaborative) as factor 2, and the pre-test score as covariate. Factor 1 allows us to evaluate the effect of the instruction on students' learning outcome (e.g. whether procedural instruction improved the outcome in the procedural post-test more compared to conceptual instruction). Factor 2 allows us to evaluate the effect of collaboration on the two knowledge types. Furthermore, we analyzed the differential effect of collaboration with two a priori contrasts: individual vs. collaborative learning within the procedural condition, and individual vs. collaborative learning within the conceptual condition (for the contrasts, only significant results are reported).

Different covariates were included for the analyses of the various parts of our tests in the learning and the post-test phase: For the procedural variables (error rate of the procedural conditions, procedural near and far transfer), we included the pre-test scores from the procedural problem set as covariate; for the conceptual variables (error rate of conceptual conditions, conceptual near and far transfer), we included the pre-test scores from the conceptual problem set as covariate. For the combination problem set, the covariate combined procedural and conceptual pre-test scores: We z-transformed both test scores and merged them to a new variable. Student performance during the learning phase was compared using individual student data from the individual conditions and dyadic student data from the collaborative conditions; the covariate in the collaborative conditions was the dyads' average pre-test scores. For the test phase, both partners of each dyad were included in the analysis as an interclass correlation analysis had confirmed the independency of partners' results (for all correlations $p > .10$).

Table 2: Means and standard deviations of students' performance during learning phase and post-test

	Procedural conditions		Conceptual conditions	
	Individual	Collaborative	Individual	Collaborative
Learning Phase				
Error rate	.19 (.10)	.18 (.05)	.52 (.15)	.47 (.04)
Time before action	17.88 (6.47)	16.85 (1.74)	34.37 (13.27)	46.45 (5.45)
Time after error	23.86 (7.44)	19.27 (3.16)	24.49 (14.67)	26.10 (11.66)
Post-test: procedural problem-set				
Near transfer	6.60 (3.65)	5.80 (3.36)	5.60 (3.44)	5.30 (2.41)
Far Transfer: errors detected	5.00 (1.31)	3.40 (1.06)	3.40 (1.14)	3.20 (1.87)
Far Transfer: errors corrected	3.60 (2.07)	2.60 (1.17)	1.80 (1.30)	1.80 (1.14)
Post-test: conceptual problem-set				
Near transfer	5.20 (2.68)	4.20 (1.48)	5.00 (2.74)	4.90 (1.23)
Far Transfer: errors detected	2.00 (.71)	2.10 (.74)	2.00 (1.00)	2.30 (.67)
Far Transfer: errors corrected	.40 (.89)	.30 (.48)	1.20 (.84)	.60 (.84)
Post-test: combination problem-set				
Derive equation	.80 (.84)	.60 (.52)	.60 (.89)	1.30 (.82)
Correct solution	.80 (.84)	.20 (.42)	.40 (.55)	.90 (.57)

Note: Time before action and time after error are measured in seconds.

Student Behavior in the Learning Phase

Comparison of Performance

First, we compared the performance of students in the individual and the collaborative *procedural condition*. The analysis showed a significant influence of procedural prior knowledge as assessed in the pre-test (covariate) on students' *error rate*, F (1,7) = 3.55, p = .10, η^2 = .17. However, no difference between conditions was found, F < 1.00. Second, we compared the performance of students in the individual and the collaborative *conceptual condition*. Again, prior knowledge assessed as the conceptual pre-test score showed a significant influence on students' *error rate,* F (1,7) = 14.72, p < .01, η^2 = .68, while no difference between conditions was found (F <

1.00). As the analysis revealed, students only solved about half of the problems correctly (average error rate across conditions .49). Since the problems in the conceptual instruction were multiple choice, i.e., students had to judge for each story problem if it was consistent with the equation or not, student performance was only on par with the random statistical expectation.

Comparison of Process Variables

The two-factorial analysis of the process variables *time before action* and *time after error* revealed interesting differences between conditions. First, conditions differed regarding the variance of the variable *time before action,* $F(3,16) = 11.95$, $p < .01$: Particularly the individual conditions showed a high variance, while in the collaborative conditions, the dyads spent similar times before entering the next problem-solving action. As the analysis revealed, conceptual conditions spent significantly more time prior to actions than the procedural conditions, $F(1,16) = 42.33$, $p < .01$, $\eta^2 = .72$; however, this result is less surprising due to the differences in the learning material during instruction. We could not establish a significant difference of the factor learning situation, $F(1,16) = 2.43$, $p = .14$, $\eta^2 = .13$. The analysis revealed a significant interaction between instruction and learning situation, $F(1,16) = 3.42$, $p = .08$, $\eta^2 = .17$: While the individual and the collaborative procedural condition showed similar average times, the contrast comparing the two conceptual conditions revealed that dyads spent significantly more time before judging the concordance between the algebraic equations and the story problems than students learning individually, $F(1,16) = 5.81$, $p = .03$. A subsequent correlation analysis revealed that the time spent prior to a student action had a different meaning depending on the type of instruction material. In the procedural conditions, longer times correlated positively with higher error rates ($r = .60$, $p = .07$), in other words, particularly weak students needed time to decide on their next action; in the conceptual conditions, longer times correlated negatively with higher error rates ($r = -.73$, $p = .02$), indicating that elaboration on the translation between algebraic equations and story problems improved problem-solving.

For the variable *time after error*, the Levene test again revealed different variances, $F(3,16) = 5.13$, $p = .01$. Both for the procedural and the conceptual instruction, the process variable showed a higher variance in the individual condition than in the collaborative condition. The variance analysis did not reveal differences between conditions (for all factors $F < 1.00$). As for time before actions, we found a differential impact of conditions on the time spent after errors: In the procedural conditions, there was a trend for a positive correlation between time after errors and error rate ($r = .40$, $p = .25$); in the conceptual conditions, we again found a negative correlation between time after errors and error rate ($r = -.75$, $p = .01$), in other words, students and dyads that showed a better performance during the learning phase spent more time elaborating on errors. This is particularly interesting as the learning material of the conceptual instruction was multiple choice with two options, thus if the first answer was wrong, it was clear which choice to select. This yields the conclusion that good learners did not elaborate on how to correct the answer, but actually tried to understand why their initial choice was wrong. The increased elaboration also had a positive impact on learning: Students in the conceptual conditions who spent more time elaborating before actions and after errors, showed better results in the conceptual near transfer problems (for time before action, $r = .62$; $p = .06$; for time after error, $r = .64$; $p = .05$). In the procedural conditions, we again found a trend in the opposite direction with longer times being related to worse results in the procedural near transfer problems (for time before action, $r = -.52$, $p = .12$; for time after error, $r = -.45$, $p = .20$).

Student performance in the post-test

Comparison of Performance in the Near Transfer Problem Sets

In the *procedural near transfer* problem set, we found a significant influence of the covariate prior knowledge, assessed as the procedural pre-test scores, on the number of problems solved correctly, $F(1,25) = 11.06$, $p < .01$, $\eta^2 = .31$. Students in the procedural conditions solved significantly more tasks correctly than students in the conceptual conditions, $F(1,25) = 2.98$, $p = .10$, $\eta^2 = .11$. Neither the factor learning situation, $F(1,25) = 1.97$, $p = .17$, nor the interaction effect ($F < 1.00$) was significant. In the *conceptual near transfer* problem set, we could not establish significant differences between conditions (for the covariate $F(1,25) = 1.47$, $p = .24$; for all other factors, $F < 1.00$). As during the learning phase, students only solved about half of the problems correctly (4.72 out of 9 problems), thus their performance did not exceed statistical chance.

Comparison of Performance in the Far Transfer Problem Sets

In the *procedural far transfer* problem set, we found a significant influence of the covariate prior knowledge on students' *error detection,* $F(1,25) = 8.46$, $p = .01$, $\eta^2 = .25$. Students in the procedural conditions found significantly more erroneous problem-solving steps than students in the conceptual conditions, $F(1,25) = 6.41$, $p = .02$, $\eta^2 = .20$, and students in the individual conditions outperformed students in the collaborative conditions, $F(1,25) = 6.57$, $p = .02$, $\eta^2 = .21$. As the analysis of the contrasts revealed, the difference between individual and collaborative conditions was due to a better performance of students that had learned with procedural instruction individually when compared to students that had learned with procedural instruction in the collaborative condition, $F(1,25) = 7.81$, $p = .04$. Also with regard to *error correction*, we found a significant influence of the covariate prior knowledge on student performance, $F(1,25) = 6.89$, $p = .02$, $\eta^2 = .22$. Again, the procedural conditions outperformed the conceptual conditions, $F(1,25) = 11.66$, $p < .01$, $\eta^2 = .32$. Neither the factor learning situation,($F(1,25) = 2.26$, $p = .15$ nor the interaction effect were significant, $F(1,25) = 1.18$, $p = .29$.

In the *conceptual far transfer* problem set, the covariate conceptual prior knowledge did not show a significant influence on the number of *errors detected* by students, $F(1,25) = 1.63$, $p = .21$. We neither found a significant influence of the factors learning situation and instruction nor a significant interaction effect (all $F < 1.00$). Also with regard to *error correction,* prior knowledge did not show a significant influence, $F(1,25) = 1.69$, $p = .21$; however, we found a positive impact of the instruction: Students that had received conceptual instruction during the learning phase corrected significantly more erroneous problem-solving steps than students that had solved procedural tasks, $F(1,25) = 3.47$, $p = .07$, $\eta^2 = .12$. Neither the factor learning situation, $F(1,25) = 1.75$, $p = .20$ nor the interaction effect ($F < 1.00$) showed significant results.

Comparison of performance in the combination problem sets

The analysis of the *number of equations correctly derived* (i.e. the conceptual problem-solving step) revealed a significant influence of the covariate that combined the procedural and conceptual prior knowledge as assessed in the pre-test, $F(1,25) = 2.99$, $p = .10$, $\eta^2 = .11$. Neither the factor instruction nor the factor learning situation showed significant on the conceptual problem-solving step (for both factors $F < 1.00$). There was a trend for an interaction effect, $F(1,25) = 2.64$, $p = .12$, $\eta^2 = .10$, that derived from a significant difference between the conceptual conditions: Students that had learned collaboratively with conceptual instruction were significantly better in setting up the equation than students that had learned individually with conceptual instruction, $F(1,25) = 3.18$, $p = .09$. This result indicates a positive impact of collaboration on conceptual knowledge acquisition.

For the number of *problems solved correctly* (i.e. both conceptual and procedural knowledge were required), the covariate did not show a significant influence ($F < 1.00$). However, the analysis revealed a significant interaction of instruction and learning situation, $F(1,25) = 6.11$, $p = .02$, $\eta^2 = .20$: In the procedural conditions, students that had learned individually outperformed students of the collaborative condition, $F(1,25) = 5.15$, $p = .03$, while in the conceptual conditions, the contrary effect was found, $F(1,25) = 3.12$, $p = .09$. Interestingly, all of the students in the procedural individual condition that had found the correct algebraic equation also solved the equation correctly (for both variables, the mean is .80). However, the overall performance of students was quite low: Only a few students were successful in setting up the equation, and on average, they merely solved 0.57 out of 3 tasks correctly.

Discussion

The analysis of students' performance and problem-solving behavior during the learning phase and the analysis of their learning outcome assessed in the post-test provide some support for our hypotheses. In the following, we will shortly summarize the study results. First, we found significant differences between procedural and conceptual instruction on student learning outcome. As hypothesized, the procedural instruction had a positive impact on student performance in the procedural problem sets of the post-test. First, students of the procedural conditions solved more procedural near transfer problems correctly than students of the conceptual conditions; second, they also outperformed students of the conceptual conditions in error detection and correction in the far transfer problem-set. In contrast, the conceptual instruction only had a minor impact on the post-test performance: Students of the conceptual conditions neither outperformed students of the procedural conditions in the near transfer problem set nor in the error detection of the far transfer problem set. However, we found a positive impact of conceptual instruction on students' error correction in the conceptual far transfer problem set. As indicated by the low performance of students in the conceptual problem sets, the conceptual tasks might have been too difficult for students, and the conceptual instruction might not have been enough to compensate for the missing prior knowledge.

The analysis of the process variables of the learning phase also revealed differences between procedural and conceptual conditions. Students in the conceptual conditions spent more time prior to actions than students in the procedural conditions. While this can be explained by the high amount of text to be read (story problems vs. algebraic equations), the meaning of the time spent prior to actions and after errors revealed different between conditions: In the procedural conditions, weaker students did not know how to approach the problems and thus needed more time for the problem-solving steps; good learners needed less time to solve a problem step, indicating that the problem-solving procedures were already automatized (cf. Anderson 1983), that is, students had already reached higher skill fluency. In contrast, in the conceptual conditions, good learners spent more time elaborating on the translation between the story problem and the equation, while weaker learners showed less time prior to solution attempts. Particularly interesting, good learners also spent more time after errors even though in these multiple choice problems, it was clear which choice to select if the first answer was wrong. This indicates that in the conceptual conditions, good learners engaged in deeper cognitive processes than weak learners in order to understand the corrections. Interestingly, this elaborative learning behavior was also positively correlated with a better learning outcome in the conceptual near transfer problems. The differences between the procedural and the conceptual instruction support our assumption that different processes are relevant for the acquisition of these knowledge types: While sufficient practice is most important for procedural knowledge acquisition, the conceptual problems require students to engage in deeper cognitive processes to translate between the different representation formats of the concepts – and these elaborative processes take time.

Since different processes are relevant for the acquisition of these knowledge types, it is likely that collaboration might indeed have a differential effect. Results from the post-tests further confirm this hypothesis. As the comparison of the individual and the collaborative procedural condition revealed, collaborative learning impeded students' procedural knowledge acquisition. Although neither in the performance during the learning phase nor in the procedural near transfer problem set did we find differences between the individual and the collaborative procedural condition, the procedural individual condition outperformed the procedural collaborative condition in error detection in the far transfer test. Furthermore, all students of the procedural individual condition that derived the correct equation in the combination problems (conceptual problem-solving step) were also able to find the right answer (procedural problem-solving step), while this was only the case for a third of the students in the procedural collaborative condition (.60 equations derived correctly, .20 problems solved correctly). In contrast, the study confirmed the effectiveness of collaborative learning for conceptual knowledge acquisition: Although we neither found differences between the individual and the collaborative conceptual condition in the performance during the learning phase and in the near and far transfer problem sets, students who had worked with a partner on conceptual material during the learning phase were significantly better in the conceptual problem-solving step of the combination problem – deriving the equation. The analysis of the learning processes showed that the advantage of the collaborative condition with regard to conceptual knowledge might be explained by students' learning processes: The collaborative conceptual condition spent more time elaborating and discussing the concordance between story problems and equations than the individual conceptual condition; as the correlation analysis revealed, the longer elaboration times were related to better performance and learning outcome.

Overall, the study revealed major difficulties of students in all conditions in solving the conceptual tasks. First, student performance both during learning and post-test phase was only on par with the random statistical expectation. Second, in the combination problem set, only a few students were successful in setting up the equation, and on average, they merely solved 0.57 out of 3 tasks correctly. This result is consistent with the difficulties of students regarding story problems which are often reported in the literature (e.g. Brenner et al., 1997) and indicates an increased need in supporting students' acquisition of conceptual knowledge.

So far, the analysis of the learning phase concentrated on quantitative variables. In the future, we also plan to analyze students' interaction during the learning phase with a qualitative approach. Particularly, this can help us to gain a better understanding of the differences between the learning processes during procedural versus conceptual instruction. For instance, one could hypothesize that the collaboration on the different task types evoke different interaction processes (cf. Dillenbourg et al., 1996): Procedural instruction might rather yield interactions on a low level of elaboration (e.g. discussing what to do next) that are less beneficial for learning, while with conceptual instruction, students might engage in deeper cognitive processes (e.g. discussing why a solution is correct or incorrect). Furthermore, the analysis of students' interaction can reveal differences in the learning processes of students that show good versus bad performance in the conceptual tasks. This might help to develop conceptual instruction that facilitate students' conceptual knowledge acquisition more effectively.

This study was an initial small scale study to establish basic effects for knowledge acquisition in the domain of algebra. Thus, the results are only suggestive, and we will have to see if they can be replicated with a larger study sample and a more stringent alpha. Nevertheless, the results are quite promising and have important implications for the school context. As the study revealed, collaboration is not always equally effective to support student learning. While we have seen that collaborative practice in applying procedures has a negative impact on procedural knowledge acquisition, we found indications that the collaborative elaboration of underlying concepts benefits students' conceptual knowledge acquisition. The analysis of the processes during the learning phase revealed that these differences can be explained by the different learning processes necessary for procedural and conceptual knowledge acquisition. In order to ensure benefits of collaborative learning in the school classroom, it thus is important to introduce collaborative learning more selectively for tasks that require students to elaborate on the mathematical concepts. Particularly for story problems that demand a solid understanding of mathematical concepts and which have shown particularly challenging for students, collaborative learning can be beneficial.

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Collaboration and Knowledge Integration

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Abstract: We draw on three examples from the Technology Enhanced Learning in Science (TELS) project to show how collaborative activities designed following knowledge integration patterns contribute to science learning. By knowledge integration we refer to learners sorting out their many, often contradictory, ideas to develop coherent understanding. Research on instruction suggests four interrelated processes that jointly lead to integrated understanding: eliciting current ideas, adding new ideas, evaluating ideas, and sorting out ideas. These processes characterize design patterns that promote knowledge integration. We describe how knowledge integration patterns informed the design of collaborative activities for Chemical Reactions and report on the value of heterogeneity in small groups. We describe how teachers learned from each other while refining an on-line teacher's guide for Asthma. We describe how teachers engaged in collaborative customization of the plate tectonics unit and show that the revised unit resulted in improved student learning.

Introduction

Designing effective collaborative activities has proven difficult (Linn & Eylon, 2006). One goal of the knowledge integration framework is to help people learn from each other. TELS technologies and professional development materials have incorporated numerous collaborative experiences. TELS technologies include the Web-based Inquiry Science Environment (WISE) and Teacher Guides. In prior work we have identified design principles (Kali, 2006) and design patterns (Linn & Eylon, 2006) that promote knowledge integration. Designers used these patterns and principles in the process of creating instructional materials. The NSF-funded TELS research program involves over 7 school districts and 100 teachers across the United States. Here we report on three successful efforts and show how they benefitted from knowledge integration patterns or principles.

Supporting Student Collaboration in Chemical Reactions and Asthma

Chiu (2009) designed the chemical reactions unit using knowledge integration patterns (Linn & Eylon, 2006). A key premise of knowledge integration is that students hold multiple ideas about any scientific phenomena. The knowledge integration pattern helps learner sort out these ideas by: eliciting ideas so that learners become aware their views of the situation, adding ideas to fill in missing information to make sense of the topic, developing criteria for distinguishing among ideas so that students can determine which ideas to promote, and reflecting and synthesizing ideas by reviewing the repertoire of ideas and developing more coherent views. TELS technologies support each of these aspects of the knowledge integration pattern with multiple activities. Here are some examples from the Chemical Reactions and Asthma units.

Eliciting ideas. The *Chemical Reactions* unit uses an online brainstorming step to elicit students' ideas about the greenhouse effect and global warming (Figure 1). Through the brainstorm, pairs of students can collaborate with each other and with other pairs to elicit a rich repertoire of ideas.

Figure 1. Screenshot of the TELS brainstorm tool used in Chemical Reactions to elicit students' ideas about climate

Adding ideas. Often the normative ideas about a topic are missing and new ideas are needed. Each TELS activity features powerful visualizations to help students add ideas about processes that cannot be easily observed. In *Chemical Reactions*, students experiment with a visualization of hydrogen combustion. Students can observe intermediate states in a reaction, determine the effect of adding heat on molecular motion, or trace the path of a single atom. Student pairs are guided to focus on a series of aspects of the visualization: a) how the spark provides energy, b) how the atoms combine and change, c) how chemical equations link to the visualization, and d) how the visualization connects with observable phenomena. By guiding students to revisit the models with slightly different foci each time, the curriculum helps reduce the complexity of the visualizations and take advantage of the varied levels of expertise in the class.

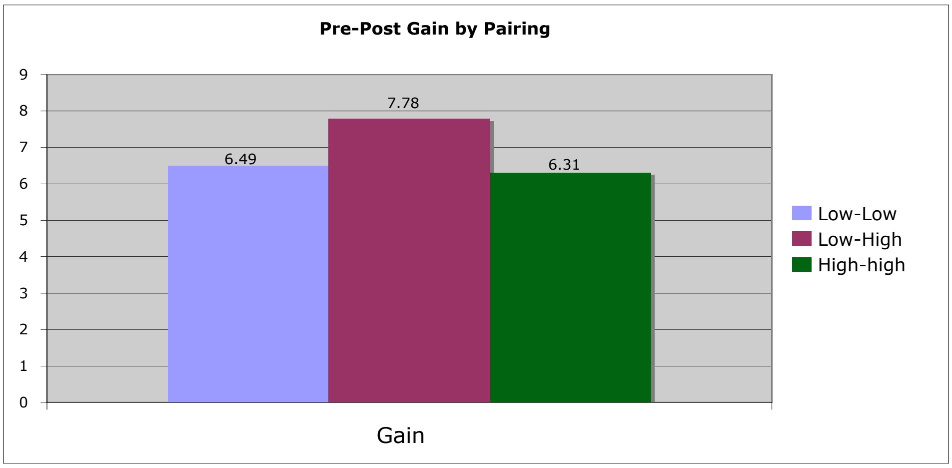

Figure 2. Average gains from pretest to posttest for groups using *Chemical Reactions* according to a median split. Homogeneous pairs consisting of two students below or above the mean gained about the same (low-low: n=30 pairs, M(SD)=6.49(2.98); high-high: n=45 pairs, M(SD)=6.31(3.31)) whereas students in heterogeneous pairs with one student above the mean and one below gained more (low-high: n=56 pairs, M(SD)=7.78(3.58).

Evaluating ideas. Pairs of students discuss these new ideas and try to distinguish them from existing ideas. Teachers often model the process of evaluating ideas and help students develop criteria to use in comparing ideas. The peer critique activity in the *Asthma* unit guides students to create a rubric that make explicit the criteria for a well-supported decision. Students use the rubric to critique each other's decision justifications. The peer feedback informs not only their revisions of their justifications, but also the connections they make between new and existing ideas.

Reflecting and sorting out ideas. After brainstorming their ideas, student pairs review the kinds of chemical reactions that contribute to greenhouse gases (hydrocarbon combustion), and explore other kinds of chemical reactions that may be more environmentally friendly (hydrogen combustion). To sort out their ideas, students write a letter to their congressperson describing how chemistry relates to climate change. Students are encouraged to use notes from the entire project to construct their letter, which is posted in an online discussion for the class to comment and critique. This online discussion allows students to synthesize and refine connections among ideas collected throughout the project.

These TELS activities offer students the opportunity to assume multiple roles, a key advantage of collaborative learning. For instance, a student may be an expert at explaining how chemical reactions relate to energy, yet be a novice at interacting with dynamic visualizations. The partner student may have expertise in constructing models, yet struggle to design consequential experiments. Each TELS unit enables students to take advantage of the expertise of their partners.

Our findings support the combination of students with varied expertise. In one study, we paired students based on pretest scores (Chiu, 2009). We performed a median split and created pairs with 2 high scores, 2 low scores, or one high and one low. Preliminary findings suggest that pairing students with different levels of prior knowledge benefits both members of the pair more than grouping students with similar prior knowledge (Figure 2). This finding is consistent with the idea that students with varied prior knowledge can help each other add ideas to their repertoire.

Supporting Collaborative Design of the Asthma Teacher's Guide

We explored an online Teacher's Guide to help teachers share ideas about teaching for knowledge integration. Teachers play a significant role in the success of curriculum intended to promote knowledge integration. Teachers manage the presentation of content, determine the appropriate scaffolds that support student learning, and coordinate the time and materials necessary to create an effective learning environment (Schneider et al, 2005; Tal, Krajcik & Blumenfeld, 2006). The Teacher's Guide promotes teacher learning by encouraging the integration of ideas from multiple users. We studied this process with the *Asthma* unit guide.

Collaborative Design of Teacher's Guide. To support teachers' enactment of the *Asthma* unit, the design team, comprised of education, science, and community partners, developed the online Teacher's Guide based on the experiences of the first users (Novia, 2007). The Guide communicates the objectives of each TELS activity, provides student materials such as evidence organizer worksheets and lab instructions, and includes specific entries related to the discipline and pedagogy.

Discipline entries provide normative explanations for the science and decision-making presented in the unit and highlight common student difficulties identified in observations and analysis of student work. For example, one entry reads, “The unit teaches three physiological symptoms of an asthma attack - airway inflammation, mucus production, and bronchial muscle constriction. Students often focus on the ideas that oxygen is restricted from entering the body. The unit also points out that carbon dioxide is restricted from exiting the body.” Pedagogy entries suggest teacher practices intended to promote student understanding. For example, “Making the Best Decision: The Supporting Your Decision step is a good point to stop the class and have a discussion. Often students are at different points in the unit, so it may be best to review this page at the beginning of a class session.”

We report on the iterative design process of the *Asthma* unit and online Teacher’s Guide (Tate et al, 2008). In three school years, ten teachers across five schools have implemented the unit in their classrooms. Each use of the *Asthma* unit has resulted in gains in student learning from pretest to posttest (Tate, 2009). Seven teachers have used and improved the online Teacher’s Guide, which provides a space for information about teaching practices to persist that users believe will improve student learning. Teachers added new activities, refined existing activities, and collaboratively redesigned activities using the Teacher’s Guide. The following examples illustrate how teachers use the online Teacher’s Guide and how it contributes to teacher learning.

Refinement of a debate activity. The first online Teacher’s Guide entry about the debate activity presented worksheets to guide students as they planned for the debate and two options to help teachers facilitate the activity. For option one, pairs of students would debate each other. Option two suggested a group format where students split up into two debate teams. In year one, all teachers who implemented the debate followed option two with varying success. Some teachers were able to effectively facilitate the turn taking of students and support them as they articulated their claims, evidence, and questions related to their decision-making. Other teachers struggled to appropriately scaffold students to participate in the highly interactive debate and were frustrated when unsubstantiated arguments went unquestioned.

In year two, three teachers revised the Guide to include tips based on successful implementation of the debate. One teacher’s revisions included adding more structure, clarifying presentation types (e.g. opening statement, rebuttal, response, and closing statement), setting time limits, and adding work periods where students come together to plan for their next presentation. Spontaneous student cross talk was limited so that students thoughtfully used their evidence to support their arguments and counter arguments. In addition, this teacher created planning worksheets and scoring rubrics for students and for teacher grading of student contributions following the knowledge integration framework. The new debate format was added to the online Teacher’s Guide and three other teachers implemented it.

Refinement of a critique activity. Analysis of student responses from year one implementations of the *Asthma* unit indicated that students needed additional opportunities to critique and construct their decision justifications. In response, the design team added a peer critique activity described earlier. Initially, the online Teacher’s Guide presented a basic set of instructions to guide teachers’ implementation of this peer critique activity. The first teacher to implement the activity designed an introductory activity where she elicited students’ ideas about what “critique” meant to them and helped students develop class criteria for critique. To scaffold the critique process, she asked the class to apply the rubric to a sample argument that she constructed. These teaching practices were added to the online Teacher’s Guide. Another teacher believed her students needed more understanding of the purpose of a critique, what a rubric is, and how it supports a critique process. To help students understand this, she created a PowerPoint presentation that explained rubrics and the features that could be included in them. She added a rating system to make the evaluation more concrete for students. The revised plans were added to the online Teacher’s Guide and three new teachers implemented them.

These examples show how collaboration around the online Teacher’s Guide can elicit teachers’ ideas about using a specific activity, add new ideas from the community, evaluate ideas in empirical tests, and support integration of these ideas. As a result, teachers benefit from expertise across a community even when the participants do not meet face-to-face. The online Teacher’s Guide allows new teachers to learn about curricular objectives, access suggested practices, and report back on their experiences.

Supporting Collaborative Customization of Plate Tectonics

TELS assessment and feedback tools promote the exchange of ideas between teachers and students. TELS embedded assessment questions make students’ thinking visible as they work through a project adding, distinguishing and integrating new ideas. This gives teachers insight into students’ reasoning and level of understanding, which allows teachers to customize their instruction and feedback to students based on their individual students’ needs.

Using evidence from student work. Embedded assessments capture student thinking in the moment and make it available to teachers. These artifacts give teachers insight into the coherence of students’ knowledge, and the ways that students make sense of novel curricular elements such as the dynamic visualizations. Teachers can collaboratively review these comments in professional development workshops. The goal of TELS professional development is to help teachers consider and practice using the evidence from the embedded assessments combined with classroom observations and guidance from experts (e.g. mentor teachers, curriculum and assessment developers, scientists, technologists) to customize their instruction based on their students' expressed ideas. Teachers participate in annual, 5-day summer workshops and are supported by a selected mentor teacher during the school year.

Workshops are designed based on the knowledge integration framework. The TELS professional development workshops *elicit teachers' ideas* about technology-enhanced inquiry instruction in discussions of pedagogical dilemmas. We provide opportunities for teachers to *add new ideas* by collaboratively analyzing student work on embedded assessments, sharing curriculum implementation experiences, and participating in discussions about instruction with experts. Teachers are supported to *distinguish their ideas* by negotiating criteria with colleagues to categorize the range of their students' thinking according to a knowledge integration perspective. The professional development activities provide opportunities for teachers to *sort out and connect ideas* as they collaboratively link analyses of their students' reasoning with customizations to their inquiry project and associated pedagogical strategies.

To examine how mentored customization of instruction in professional development impacted teachers' interactions with their students, we analyzed longitudinal data from three teachers who participated in TELS professional development and taught the same TELS unit (*Plate Tectonics*) for at least two consecutive years. We investigated the customizations teachers made to the unit, their associated teaching strategies, and the effects of their customizations on student learning outcomes (Gerard, Spitulnik, Lee & Linn, 2009).

Analyses suggest that teachers' use of TELS embedded assessment data in the summer workshop changed the way that the teachers interacted with their students' ideas in the classroom. In terms of curricular customizations, the most frequent categories of customization were *adding information* and *modifying embedded assessment questions or text.* Customizations primarily helped students focus on the key concepts in the computer models, or emphasized the key points in the embedded assessment questions. These curriculum customizations allowed students to work more autonomously through the *Plate Tectonics* unit, providing the teacher greater opportunity to facilitate learning. This is evidenced by the change over time in teachers' pedagogical strategies.

Teachers demonstrated the greatest changes over time in their teaching practice in terms of *increasing assessment, using physical models* and *promoting good discussions* when teaching the *Plate Tectonics* unit. This suggests that as teachers gained more experience with the TELS unit and more practice in the summer workshop using students' ideas to customize their instruction, they created more opportunities to listen to their students' thinking while teaching the TELS unit, and interleaved additional opportunities for students to interact with the concepts such as laboratory activities and homework.

To determine how teachers' use of ideas to customize instruction impacted their students' knowledge integration, we analyzed students' pretest and delayed posttest results for three years. Regression analysis shows that with each year teachers engaged in evidence-based customization of instruction, their students' learning gains significantly improved (Figure 3). The impact of the professional development was greatest after teachers had 1 year of experience customizing the curriculum (Gerard et. al, 2009).

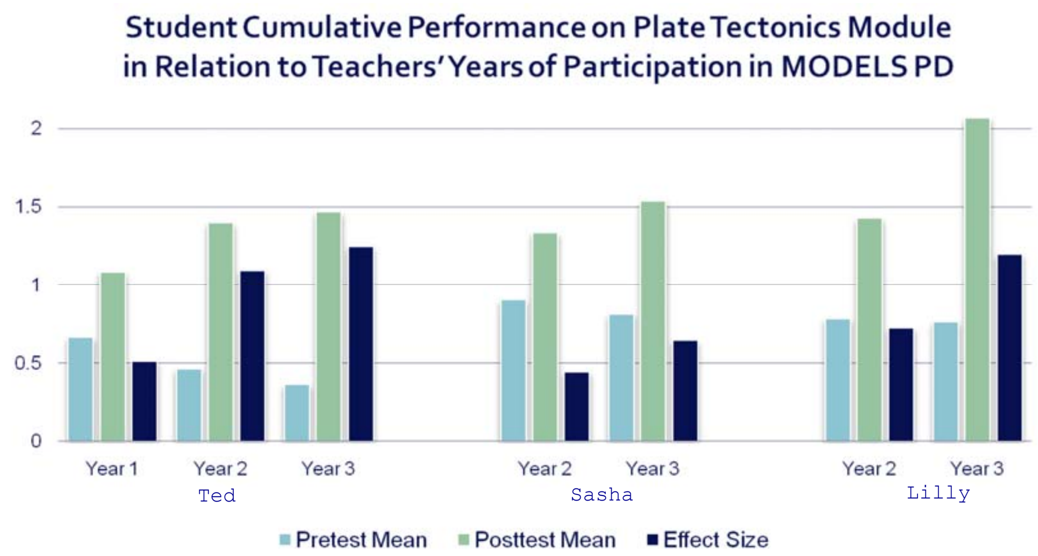

Figure 3. Impact of collaborative customization on student learning over three years.

Designing online feedback. We examined how teachers use TELS assessment and feedback tools to listen to and provide targeted feedback to facilitate students' knowledge integration. Teachers who participated in the Year 2 summer workshop were concerned about how to provide timely feedback to students during a TELS project; they rarely had time to write individual comments to each student for each assessment. To address this problem, the teachers started by creating unit-specific feedback using the knowledge integration rubric. Teachers who taught the same TELS unit jointly selected a few key questions and graded a random sample of student work. They identified student ideas that fit the five levels of knowledge integration and created specific rubrics for these items.

The teachers then designed feedback for specific responses that was intended to motivate learners to improve the integration of their ideas. The teachers worked in small groups, mixed by school and grade level, and focused on one of the knowledge integration categories. They created a variety of options that could be applicable to students' work in multiple TELS units as well as responses specific to each unit. Each teacher then entered the comments they would like to use in the upcoming school year into the Teacher Portal. Using the portal they could then assign responses rapidly to multiple student groups.

This collaborative activity had several benefits. First, the teachers gained valuable insights into the ideas held by their students. Second, the agreed-upon responses motivated teachers to provide more feedback to their students. Specifically, we analyzed the feedback given by six teachers, one from each grade level at both schools in the two school districts. In the year prior to this professional development activity, the teachers provided a total of 1788 comments (about 300 comments per teacher). After the professional development the teachers gave a total of 4302 comments (about 700 comments per teacher), a significant gain. By supporting collaborative design of comments and providing an easy way to store and use comments, the professional development dramatically increased targeted feedback to students.

Conclusions

Knowledge integration patterns and principles inform the design of curriculum, assessments, and professional development activities in TELS. As these examples illustrate, the framework leads to successful collaborations. Using knowledge integration patterns to design the Chemical Reactions unit creates opportunities for students to help each other achieve an integrated understanding of science topics. Collaboration around the online Teacher's Guide for the Asthma unit illustrates how teachers can build on their past practices, incorporate appropriate customizations made by their peers, and reuse effective materials. Support for evidence-based customization in professional development using knowledge integration patterns can lead to curricular revisions that result in improved student understanding.

These examples show that collaborative experiences can contribute to improvement in learning outcomes for students and teachers. These efforts succeeded, in part, because of the alignment of curriculum, assessment and professional development with the knowledge integration framework. Results from these studies underscore the importance of taking advantage of the varied expertise in the learning situation; when students, teachers, and teachers and students pool their knowledge they have a better chance of making progress. Investigations illustrate the value of technology-enhanced curricula in terms of making information (e.g. students embedded assessment responses, teachers' suggestions for implementing a particular activity in Teacher Guide) accessible over time, enabling learners to benefit from the expertise of others.

These studies suggest that the knowledge integration patterns add value to collaborative experiences. Combining the patterns and the evidence from the technology amplifies the impact of collaboration on teacher and student learning. These combinations benefit from trial and refinement as seen in the refinement of the Teachers' Guide for *Asthma*, the customization of the *Plate Tectonics* unit, and the iterative design of *Chemical Reactions*. We are capturing effective refinements in elaborations of the design patterns. Using the patterns to design curriculum and professional development can increase the impact of collaboration on teacher and student learning.

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Collaborative Scientific Conceptual Change: A Framework for Analyzing Science Learning

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Abstract: One problem in science education is that students neither construct in-depth conceptual understanding nor are they able to apply scientific thinking processes. A myriad of studies on conceptual change have investigated the nature and process of conceptual change, pedagogical strategies to foster conceptual change and improve higher-level thinking. We propose a new framework - the collaborative scientific conceptual change model – to stresses the importance of high quality collaborative discourse and scientific epistemic practices in the process of conceptual change. To investigate how group interactions influence individual students' learning gains, multilevel analysis was used to analyze the hierarchically nested data and qualitative analyses were presented to compare high and low-achievement groups' discourse and their application of epistemic practices. The results found that predicting and coordinating theory and evidence were key practices that predicted students' individual posttest performance and the group interactions were related to the group understanding.

Introduction

One problem in science education is that students neither construct in-depth conceptual understanding nor are they able to analyze and apply scientific thinking processes (National Research Council, 1996). A myriad of studies on conceptual change have investigated the nature and process of conceptual change, pedagogical strategies to foster conceptual change and improve higher-level thinking. One common instructional strategy is to confront students with discrepant events, causing cognitive conflicts, which is widely accepted to be essential for conceptual change (Posner, Strike, Hewson, & Gertzog, 1982). However, other researchers propose that conceptual change is a gradual process and argue that adults, children and even trained scientists fail to change their theories when faced with conflicting evidence (Chinn & Brewer, 2001). Accordingly, other factors must be considered, such as peer interactions and engagement in the epistemic practices of science. We propose a new theoretical framework - the collaborative scientific conceptual change (CSCC) model - to explain conceptual change processes.

Collaborative Scientific Conceptual Change Model

Conceptual change is not easy to achieve because students tend to use their intuition to explain science concepts, which can lead to superficial understanding that may be resistant to instruction (Chi, 2005). Posner et al (1982) believe that conceptual change is a rational process "by which people's central, organizing concepts change from one set of concepts to another set, incompatible with the first" (p. 211). In addition to the cognitive aspect, social constructivists insist that knowledge develops through social negotiation and through the judgment of the application of the ideas of others. The distributed nature of cognition suggests that conceptual change requires communication among people (Pea, 1993). The features of collaborative learning may help students converge differentiated meanings as they construct meanings for scientific concepts. Peer discourse may create an awareness of the need for knowledge revision and encourage the deep processing needed for conceptual change (Roschelle, 1992), and may help create joint interpretations through phases of negotiation focused on shared information (Suthers, 2006).

However, collaborative learning is not always productive as students may not see science as a process of formulating researchable questions, conducting experiments to test ideas, and formulating evidence-based argumentation (Carey & Smith, 1993; Sandoval & Reiser, 2004). Southerland, Sinatra, and Matthews (2001) believe that knowledge is "understood to be based on an assessment of evidence (in the case of scientific knowledge, the evidence would be judged using scientific epistemic criteria)" (pp. 337-338). Students need more opportunities to develop sophisticated epistemic practices such as testing and modifying ideas through experimentation and evidence-based argumentation. Computer tools may support coordinating social interactions and provide opportunities for learners to test their ideas, and coordinate theory and evidence in coherent ways.

Taken collectively, we suggest an integrated model – the collaborative scientific conceptual change model (CSCC), which involves three major elements within conceptual change: the cognitive conflict, the collaborative discourse, and the epistemic practices of science. Collaborative scientific conceptual change occurs when learners co-construct new knowledge and make a shift from their previous ways of thinking towards the scientific ways of thinking that scientists are inclined to use to explain phenomena. This framework stresses two factors in student conceptual change: the effect of social interactions and the shift towards epistemic practices of science. The reciprocally facilitating relations between collaborative discourse and epistemic practices combine the two perspectives together. On one hand, in the computer-supported collaborative learning context, collaborative discourse makes students' epistemic practices visible and available for comparison. On the other hand, the epistemic practices of science require that students use evidence to support their claims thus producing productive discourse. In this paper, we report on a classroom study using the collaborative scientific conceptual change framework to investigate trajectories of conceptual change in a simulation-supported collaborative learning context. In the study, computer simulations were used as a media to provide opportunities for students to conduct science observation, collaborative argumentation, and experimentation.

Methods

The participants were 145 middle school students from two public schools who participated in this study as part of their science instruction. Two different teachers, Teacher A and Teacher B, were experienced science teachers. The teachers randomly assigned students to groups. Twenty focal groups' interactions were videotaped.

To facilitate students' understanding of the aquarium ecosystem, we developed two NetLogo simulation models (Wilensky & Reisman, 2006). The two simulations (the fishspawn model and the nitrification process model) present system characteristics at different scales. The fishspawn model is a macro level model, simulating how fish reproduce in a natural environment. The nitrification process model is a micro level simulation of how chemicals reach a balance in an aquarium. This simulation allows students to examine how bacterial-chemical interactions affect the water quality represented in the macro level simulation.

To assess learning, students completed pre- and posttests, which asked students to draw all the parts of an aquarium and label the diagram, followed by questions and problems to elicit knowledge about the aquarium ecosystem. For the 20 focal groups, videotapes of students working with the computer simulations were transcribed.

Pre- and post-tests were scored using a structure-behavior-function (SBF) coding scheme as a measure of conceptual understanding (Hmelo-Silver, Marathe, & Liu, 2007). SBF theory describes a complex system's multiple interrelated levels, and its dynamic nature (Goel et al., 1996). Prior research has demonstrated that this is a sensitive measure of student' complex system understanding (Hmelo-Silver et al. 2007; Liu et al., 2006). Parts of the system, such as fish or filter, were coded as structures. Mechanisms were coded as behaviors (e.g., the behavior of plants is to absorb carbon dioxide and produce oxygen through photosynthesis). Functions were coded for roles of different parts (e.g., function of filter is to clean water).

Two coding schemes (see details in Liu, 2008) were applied to the transcribed discourse at the level of conversational turns. The collaborative discourse codes were designed to uncover cognitive and metacognitive processes underlying the groups' discourse as well as the facilitators' roles. The epistemic practices codes examined how students engaged in the practices embodying scientific ways of thinking and how learners engage in knowledge construction (Duschl & Osborne, 2002) to build their understanding. An independent rater coded 20% of the data and the overall agreement was greater than 90%.

Results

Multilevel Analysis

To investigate how group interactions and teachers' facilitation influence individual students' learning gains, multilevel analysis (MLA) is used to analyze the hierarchically nested data (Snijders & Bosker, 1999). In this research, there are three levels of hierarchically nested data: individual student (Level 1), group interaction (Level 2), and teachers' facilitation (Level 3). The MLA analysis focused on identifying the variables in collaborative discourse and epistemic practices that could predict individual student's posttest performance as a function of group-level interaction and teacher-level characteristics. The multilevel model was constructed using the group-level interaction categories and teachers' facilitating categories as predictors of the dependent variable – TotalBF scores in the posttest. We use the total behavior and function scores as the dependent variable as this accounts for variability in deep understanding (Hmelo-Silver et al, 2007). The significant coefficient for the fixed variables demonstrates which characteristics of collaborative discourse and/or epistemic practices at the group level predict individual students' learning outcomes in the posttest.

The goal of the MLA was to explore how group-level variables affected students' learning. For the measures of collaborative discourse and teacher's facilitation, only Warranted claims significantly predicted learning outcomes ($\beta=95.82$, $t(58)=2.16$, $p=.03$). This indicates that the more warranted claims produced in the group discourse, were associated with higher learning outcomes.

Of the epistemic practices, three codes were significant predictors for TotalBF: Coordinate Theory-Evidence ($\beta=104.19$, $t(72)=2.74$, $p=.01$), Modify Knowledge ($\beta= -144.16$, $t(72)= -2.11$, $p=.04$), and Predict ($\beta=54.80$, $t(72)=2.18$, $p=.03$). This suggests that engaging in two of these three sophisticated epistemic practices within a group was associated with enhanced learning outcomes. We are not sure how to interpret the negative effect of modifying knowledge, however in inspecting the frequencies, we note that this is a very low frequency event and this may be a result of a restricted range so we would be cautious about any generalizations.

Qualitative Analysis

The qualitative analysis takes a close look at the conversational discourse within groups of students to provide further evidence for the inferences drawn from previous quantitative analysis and to identify the patterns occurred in group interactions that may have effect on the quality of collaborative activities. Four groups (including two highest-achievement and two lowest-achievement) were selected based on the group mean score of TotalBF scores and their final understanding level of the Nitrogen Cycle, which is essential for understanding the whole system.

Differences in Discourse Patterns

Compared to the two lowest-achievement groups, both highest-achievement groups made more efforts to ask explanation questions and generate warranted claims. The lowest-achievement groups asked more fact questions. Different types of questioning provide different opportunities for students to learn. Explanation questions require peer students to justify their responses, thus engage the group in the scientific practices of explanation and argumentation and provided an invitation for the group to generate warranted claims and check the accountability of proposed ideas (Duschl, Schweingruber, & Shouse, 2007). The following excerpts from one high-achievement group illustrate how an explanation question drove warranted claims and affected the tool-based activities:

139. Brad: Look at this, why is there so many small fish?
140. Ada: Increasing the water quality increases spawning. So let's leave everything alone.
141. Ada: So you guys want to try what the higher one (water quality) does. Okay, ready?
142. Ada: Look at the spawn, is like 1460 right now.

In the dialogue above, based on what he saw in the Fish Spawn simulation model, Brad asked an explanation question (Turn 139), "why is there so many small fish?" This question drove Ada's warranted claim (Turn 140), "Increasing the water quality increases spawning." And Ada continued to run an experiment in the model to test his justification. This example illustrated how simulation models mediated students' high-level thinking by stimulating explanation questions and affording opportunities to test one's warranted claims.

In contrast to explanation questions, the answers to fact questions are straightforward and largely oriented towards retrieving declarative knowledge and engaged less cognitive activities. That is, fact questions may only stimulate students to search information in their existing knowledge and they may fail to make causal connections. In simulation-based learning, students often come up with a lot of fact questions, such as "what is the yellow?", "what is the blue?" "What just happened?" These questions do stimulate students to describe their observation or even come up with a theory. However, the fact questions failed to help students develop causal relations between what they observed and the generated theory.

Differences in Epistemic Practices

The highest-achievement groups engaged in more practices like predicting, designing experiment, and coordinating theory-evidence during the collaborative activities. These are sophisticated epistemic practices that scientists use to conduct scientific exploration. To illustrate, an example from a high-achievement group discussion presented how this group of students used the simulation tools to explore science:

130. Ada: The water quality do nothing to the fish ...
131. Brad: I think that it will go up in like a second…
132. Ada: If you increase the number of pspawn, the water quality goes down. It's negative now.
133. Ada: The water quality decreases because of the population.
134. Brad: Try it.
135. Ada: Look at this, look at this. It goes down to zero, right?
136. Ada: Negative 400.
137. Brad: The water quality decreases.
138. Siddarth: Yes, it did make sense. If you increase the filter flow the water gets clean, and then it kills all the things that kill the fishes.

At the beginning, the students presented alternative hypotheses on "water quality". Ada at first predicted that water quality had nothing to do with fish (Turn 130). Brad predicted the water quality should go up (Turn 131), and Ada came up with a hypothesis to predict the relation between water quality and population (Turn 132). Then Brad suggested to do an experiment saying "Try it" (Turn 134). Through the observation, Siddarth concluded that increasing filter flow made the water clean and it killed all the organisms in the tank (Turn 138). Judging the content, the students presented a lot of problematic propositions. However, they were operating in the way that scientists normally do. First propose problematic hypotheses, then conduct an experiment to test them, and finally draw a conclusion that might still be problematic. An important finding from recent work is that students with more sophisticated epistemologies seem to take better advantage of inquiry-based learning opportunities (Windschitl & Andre, 1998). As theory theorists assume that even young children have their own theories to explain the world, it is important to acknowledge the capability of young students to learn science. Therefore, although the reasoning was not perfect and lacked coherence here, the group in the example did exhibit the tendency of using scientific way of thinking as well as sharing distributed cognition to co-construct conceptual understanding of the materials presented in the simulation model.

By contrast, the low-achievement groups tended to be more engaged in simple knowledge exchange without questioning and reasoning. Despite the importance of sharing knowledge among peers, to develop scientific understanding of the world, it is extremely important to provide student sufficient opportunities and experiences to develop their theories to explain the scientific phenomena. The following excerpts from one low-achievement group illustrate one typical example:

138. Robby:	What did you put so far?
139. Jean:	The fish urine drinks ammonia, the ammonia urine.
140. Robby:	Wait, the fish water bring ammonia
141. Jean:	No, the fish urine.
142. Robby:	Yea, the fish urine I meant. Yeah
……	
213. Robby:	How everything reacts in the tank.
214. Jean:	How all the acids and the fish react in the tank
215. Robby:	I just put how the acids and the fish react.

It is easy to tell that the goal of Robby and Jean was to give a reasonable answer to the question. They were sharing answers without reasoning with each other. Instead, they were just mechanically copying each other's ideas. This further corroborates that the practice of knowledge exchange is not sufficient at all to foster collaborative scientific conceptual. It is essential to involve other epistemic practices such as hypothesis testing, debate and argumentation, to occur in situated and collaborative contexts.

Discussion

The MLA analyses found that predicting and coordinating theory and evidence were key practices that predicted students' individual posttest performance. The qualitative analyses compared the high and low-achievement groups and found that the features of group discourse and the epistemic practices were related to the group understanding. These results are consistent with the CSCC framework, which stresses the importance of high quality collaborative discourse and scientific epistemic practices. Scientific knowledge is comprised of theory and empirical evidence. It is crucial to interrelate these two pieces together to understand what science is and how it works (Kuhn & Pearsall, 2000). Coordinating theory and evidences produces explanations to integrate hypothesized theories and collected evidences from the simulating activities. The results of this study implicate that students need opportunities to experience the mechanisms of collaborative scientific conceptual change and need to use the intentional and deliberate mechanisms that scientists use to restructure knowledge in a social process. These intentional mechanisms often include cycles of hypothesizing, testing hypotheses, generating theories, negotiating, and revising theories. Further research is needed to refine the theoretical framework by addressing questions such as how students' collaborative discourse and/or epistemic practice patterns evolve during the conceptual change process.

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Failures and Successes in Collaborative Inquiry: Learning the Physics of Electricity with Agent-Based Models

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Abstract: This paper presents a process-oriented case study of successes and failures in collaborative inquiry. The interactions of pairs were recorded and transcribed while they were engaged in learning activities, mediated by agent-based NetLogo electricity models. Transcripts of learner interactions were coded for engagements in science inquiry. The purpose of this paper is to articulate the dynamics of collaborative science inquiry approach resulting from varied scaffolding and consistent scaffolding in learning activities. Our findings indicate that students under a varied scaffolding approach were more deeply engaged in inquiry process and performed better on model-based explanations.

Introduction

Traditional pedagogical approaches that focus on algebraic models for teaching the topic of electricity are common practice in schools. Some research shows that even after extensive instruction, students do not grasp some of the very basic characteristics of an electric circuit (e.g., Mulhal, Mckirrick, & Gunstone, 2001). Students often conduct laboratory-based electricity experiments that typically involve activities leading to collection of data to verify, for example, Ohm's Law or the formula for effective series resistance; nonetheless, the curricula materials or real laboratory experiments about electricity seldom engage students to understand underlying physical phenomenon. The cognitive processes needed to succeed at many school-related tasks are often qualitatively different from the cognitive processes needed to engage in real scientific inquiry (Chinn & Malhotra, 2001). The use of technology such as computer models and visualization has been the focus of recent research to support model-based inquiry (Edelson,, Gordin, & Pea, 1999). An important issue in science education today is how to design curriculum and instruction that will enhance authentic scientific inquiry and promotes ability to apply the knowledge in novel problem-solving situations.

Curriculum and Instructional Approach

In this study, we developed learning activities for four NetLogo Agent-based models: Coulomb's law, Ohm's law, series circuit, and parallel circuit (Wilensky, 1999). Each model had three learning activities. The NetLogo models allow students to view microscopic physical phenomenon aggregating to macro-level outcomes over a period of time. The NetLogo electricity models have been used in the United States with the scaffolded activity sheets, which prompts them with logging observations, reflective tasks and questions, and relevant content knowledge (Sengupta & Wilensky, 2008). We incorporated a Productive Failure (PF) approach (Kapur, 2008) and a traditional approach (Non-productive Failure: N-PF) to design and sequence the NetLogo mediated learning activities, both approaches targeted at model-based problem solving. All the activities for PF as well as N-PF group include model-based problem. The N-PF group receives the design of the experiments in NetLogo environment, in activity 1 as well as activity 2, similar to traditional laboratory instruction. The PF group receives the design of experiments only in activity 2. Activity 3 is envisioned as an alternate assessment tool (Zhang, Jacobson & Kim, 2006). The PF approach postulates that appropriately designed *non-scaffolded* initial learning activities may eventually lead to more productive learning gains than scaffolded early experiences that do not allow students to fail.

Table 1: Sequence of Activities

	Activity 1 (20 min)	Activity 2 (20 min)	Activity 3 (20 min)
PF	Not Scaffolded	Scaffolded	Not Scaffolded
N-PF	Scaffolded	Scaffolded	Not scaffolded

In this paper, we will provide a process oriented qualitative description of interaction of two student pairs, one using the PF approach and the other using N-PF approach, to explore the relationship between the scaffolding approaches and NetLogo mediated collaborative learning of physics of electricity. Building on the idea of productive failure, we argue that the productive success in model-based explanation comes from cycle of failures and successes.

Selection of Cases

Six pairs of participants from each condition (PF and N-PF) from two schools were selected based on their previous school test scores (high, medium, and low) to collect process data as they worked together. We captured their computer screen along with webcam videos and audio recordings. Clarity problems with the audio and other technical mishaps during recordings limited our choice to have a complete data set for students with similar abilities. As a result, described below are the collaborative inquiry processes and performance on activity 1 and 2 of two pairs: Jian and Mick represent the N-PF group, and Ben and Ruo represent the PF group. Jian and Mick were categorized as having overall high academic achievement by the teacher whereas Ben and Ruo were regarded as medium achievers.

Collaborative Inquiry Process in Two Cases

The test performance indicated the PF group's significant better improvement compared to the N-PF group (see, Pathak, et. al. 2008; Jacobson, Kim, Pathak, & Zhang, 2009). Our hypothesis was that PF group would struggle to explore different ideas and approaches for solving the non-scaffolded initial problems for each of the four NetLogo models during first activity. In doing so, they might cognitively explore a wider range of ideas and concepts than N-PF students who are likely to follow the scaffolded set of tasks as is generally done in traditional laboratory settings. The following questions guided our research inquiry into the processes of two groups (PF and N-PF):

1. What different variable spaces have students explored?
2. How do exploration patterns change as a result of two conditions (PF and N-PF) within the model and over a set of models?
3. How do PF and N-PF conditions affect the process of scientific inquiry?

We conceive of model-based learning as a subset of science inquiry. We coded students' conversations and performance in activities based on their engagements in the following four components of science inquiry (adopted from White & Frederiksen, 1998). In our understanding, engagements on all the components over cycles of failures and successes should lead to a successful model -based learning.

1. *Generation of predictions (GP):* Students make educated guesses on possible outcomes of inquiry cycle.
2. *Design and execution of experiments (DEE):* Designing and conducting experiments with the NetLogo models for electricity require three main aspects of scientific experimentation: Convert the question in measurable attributes; Limit the predictors; and Collect and process the data accurately in presentable and analyzable formats.
3. *Experiment-based inference of relationships (EIR)*: Analyze and interpret data and their representations and look for relationships and patterns.
4. *Model-based explanations (MBE):* We define model-based explanations in electricity NetLogo model as student's ability to model and explain the phenomenon in terms of component of model (i.e., number of electrons, time, and distance).

We present below some excerpts of two pairs on Model 2: Ohm's law and Model 4: parallel circuit to discuss the dynamics PF and N-PF approaches. We first discuss N-PF group learning to understand what kind of interactions are achieved by providing scaffolding activities with NetLogo models, which might look similar to our typical classroom and laboratory practices, followed by PF group, whose interactions contrasts with those of N-PF group.

Model-Based Activities by Jian and Mick (N-PF Group)

Working with the two models, the initial scaffolded activity resulted in students setting their immediate goal to filling in the table with numbers. In both activities 1 and 2, Jian and Mick immediately focused their attention on the accurate measurement techniques (see Table 2).

<u>Success in Collaborative Measuring (Model 2: Ohm's Law)</u>

The pair carries out each measurement twice, take the average as done in a conventional measurement experiment. They are scaffolded through the table and the variables—the table and the first column and first row are given and students filled out the rest (in italics). Here, Jian and Mick successfully carried out the measurements but failed to discuss the microscopic patterns from the model (MBE) during their conversations and their answers to the activity questions in both activities (Table 2, B and D). By design, this pair's variables and space manipulations were limited to the table in the initial activity. There might be a conflict (between observation and equation-based conclusion as they are using mathematical form of Ohm's law (see, excerpt in Table 2, C) and Jian believes in manipulating it, so as to reach an answer. Though faced by apparent cognitive conflict, they did not change their belief about model function and purpose (i.e., not engaged in MBE).

Table 2: Jian and Mick's conversations and responses during Model 2 and Model 4 activity

<table>
<tr><td></td><td colspan="2">Model2: Ohm's law</td><td colspan="2">Model 4: parallel circuit</td></tr>
<tr><td></td><td>Conversations/Worksheet Responses</td><td>Engage -ment</td><td>Conversations/Worksheet Responses</td><td>Engage -ment</td></tr>
<tr><td>A. working with worksheet and model</td><td><table>
<tr><td>Collision rate with nuclei</td><td>Time taken to reach battery negative to battery positive</td><td>Current</td></tr>
<tr><td>0.5</td><td>(4.28+ 4. 06) 2 = 4.11</td><td>1.19</td></tr>
<tr><td>0.7</td><td>(6.57 + 6.34) ÷2 = 6.46</td><td>0.87</td></tr>
<tr><td>1.0</td><td>(9.17+8.72) ÷2 =8.75</td><td>0.7</td></tr>
</table></td><td>Nil</td><td>Mick: 0.5
Jian; No, I don't think so, 0.2… it's in between (raising his hand to gain attention from Ms. Tan)
Jian: (Pointing at graph, to Ms. Tan) Do I need to be exact?</td><td>Nil</td></tr>
<tr><td>B. Activity 1 questions</td><td>Q. How would you describe effect of collisions on current? Why is it so?
As the collision rate increases, the current in ampere decreases. The collision rate is inversely related to the current.</td><td>EIR (partial)</td><td>Q. What is your observation about current in both the wires? Explain why it is so.
The current in the top wire is half the current in the bottom wire us the resistance of top wire is twice that of the bottom. The higher the resistance, the lesser is the current flowing through</td><td>EIR (partial)</td></tr>
<tr><td>C. Discussing the question for Activity 2</td><td>Jian: …according to Ohm's law… "why is it so?" (reading from the worksheet) … according to Ohm's law, it states that RI=V, right?
Mick: Yes, RI=V
Jian: Hence we can reach that conclusion… current goes up, you see…can manipulate
Mick: Oh…</td><td>EIR (partial)</td><td>Ms. Tan: Did you write anything about voltage?
Jian: Higher the voltage higher the current, it's about ohm's law… directly related.
Ms. Tan: So you are using ohm's law?
Jian: Yes.
Ms. Tan: Ok, plays…but there are two variables.</td><td>EIR (partial)</td></tr>
<tr><td>D. Activity 2 questions</td><td>How are three values of time related to voltage? Why is it so?
The higher the voltage, the lower the time taken to reach battery negative to battery positive the voltage is inversely related to the time taken.</td><td>EIR (partial)</td><td>Q. Explain even if the charges are same why the current is different in both the wires.
The current in both the wires depends on the collision rate wire nuclei in both wires. The higher the collision rate, the higher the resistance in the wires.</td><td>EIR (partial)</td></tr>
</table>

Success in Collaborative Measuring (Model 4: Parallel Circuit)

By now they have gone through three NetLogo models with scaffolded activities. However, their interaction and inquiry patterns look quite similar to their earlier engagement as in model 2, which focus only on macroscopic ideas—they are focused on exacting their measurements. They also made inferences based on mathematical forms of circuit laws (partial EIR) without much explanations based on model observations as can be seen in excerpts Table 2, B. Here we see the teacher prompting (Table 2, C) that there are two variables involved, but their answer to the activity question (Table 2, D) does not reflect explanation with the two variables.

Model-Based Activities by Ben and Ruo (PF Group)

In the following excerpts and sample work from Ben and Ruo, we can see that they struggled and had short-term failures on aspects of science inquiry through the PF approach. However they were able to deepen their understanding and scientific inquiry through interacting with the NetLogo model and with each other after working together on a few NetLogo models.

Failures and Successes in Collaborative Inquiry (Model 2: Ohm's Law)

According to the video analysis, Ben and Ruo changed (Table 3, A) number of electrons, voltage, and collision rate to know the effect of collisions on current (engaged in DEE). It was done in a random manner by engaging in predictions as they did not have any prescribed settings as did the N-PF group.

Table 3: Ben and Ruo conversations and responses during Model 2 and Model 4 activity

<table>
<tr><td></td><td colspan="4">Model 2: ohm's law</td><td colspan="5">Model 4: parallel circuit</td></tr>
<tr><td></td><td colspan="3">Conversations/Worksheet Responses</td><td>Engag e-ment</td><td colspan="4">Conversations/Worksheet Responses</td><td>Engag e-ment</td></tr>
<tr><td rowspan="5">A. Activity 1 working with the model</td><td>No of electrons</td><td>Voltage</td><td>Collision rate</td><td rowspan="5">DEE GP</td><td>No of electrons</td><td>voltage</td><td>Collision rate R1</td><td>Collision rate R2</td><td rowspan="5">DEE</td></tr>
<tr><td>500</td><td>1.5</td><td>0.5,0.8</td><td>500</td><td>1.0</td><td>0.5</td><td>0.5</td></tr>
<tr><td>500</td><td>0.5</td><td>0.7, 0.2, 1.0,</td><td></td><td>0.5</td><td>0.45</td><td>0.9</td></tr>
<tr><td>2000</td><td>0.5</td><td>0.1</td><td></td><td>0.5</td><td>0.45</td><td>0.45</td></tr>
<tr><td>5</td><td>0.5</td><td>1.0</td><td></td><td>1.0</td><td>0.45</td><td>0.45</td></tr>
<tr><td>B Activity 1 question</td><td colspan="3">Q. How would you describe effect of collisions on current? Why is it so?
The current is more constant when the collision rate is low. When the electrons collide, the current drops due to resistance. When there is lets say, a numbers of about 10 electrons colliding with the nuclei at one time, the current drops by a lot. However, when there is only about one or two particles colliding with the nuclei at one, the current barely falls or the drop the current is negligible as abscond from the model.</td><td>MBE GP</td><td colspan="4">Q. What is your observation about current in both the wires? Explain why it is so.
When the resistance in one wire is half of the other wire, the current in this wire is about two times the other wire, both have the same number of electrons, with equal voltage. The wire with half the resistance compared to the other will have two times the current compact to the other wire, wire, as the electrons have move about two times faster than that of the other wire.</td><td>MBE EIR</td></tr>
<tr><td>C. working with activity 2</td><td colspan="3">Ruo: How are the three values related to voltage?
Ben: Want to use this one? (pointing to stop watch)
Ruo: Try, try. Let's check time.
Ben: Try this one (referring to the current model setting)</td><td>DEE</td><td colspan="4">Ben: Due to collision rate.
Ruo: Are you sure, it's due to collision rate? Everything goes with V=RI
Ben: Yes, the whole essay is about ohm's law.</td><td>EIR MBE</td></tr>
<tr><td>D. Activity 2 question</td><td colspan="3">Q. How are the three values of current related to voltage? Why is it so?
As the voltage increases, the current increases. When the voltage increases the time taken for the electrons to reach battery negative to battery positive decreases and as the collision rate with nuclei is constant and as the velocity so the electrons increases and as V = RI and thus current increases as the role of collision remains constant.</td><td>MBE EIR</td><td colspan="4">Q. Explain even if the charges are same why the current is different in both the wires. Despite number is electrons being the same, the current is determine by the equation V = IR, thus voltage and resistance also affects the value of the current thus even if both charges are the same. If the voltage and resistance is different the current would not be the same.</td><td>MBE EIR</td></tr>
</table>

In addition to the random exploration of the model, the main struggle during this activity for Ben and Ruo was about the meaning of the different representations. For example, they did not know changing the number of electrons represented a change in the material. They were also unable to attribute the collisions to an experimentally measurable form, such as collision rate (failure in the form of understanding the deeper form experimentation techniques/methods, measurements) and to make experiment-based inferences of relationships (i.e., not engaged in EIR) (see, Table 3, B). However, there is a hidden efficacy in such explorations that may manifest in "knowing" more about interrelated components of NetLogo model. Ruo tries to understand the relationships (Table 3, C) that bring both of them to engage in experimentation with prescribed settings. Working with activity 2, unlike their first activity, they are able to articulate the relationships based on the model observation as well as mathematical formulation (Table 3, D).

Successes in Collaborative Inquiry (Model 4: Parallel Circuit)

The analysis of their interaction with NetLogo shows that Ben and Ruo did the minimal number of settings needed to arrive at a meaningful functional relationship (i.e., engaged in DEE) by constraining the variable space (see, Table 3, A). It is important to note that the PF students could interpret the two-variable (see, Table 3, B) on the output current, unlike N-PF group (see, Table 2, B). Even in the non-scaffolded activity, students are able to explain their observation in terms of NetLogo based explanation taking into consideration the effects of three variables: voltage and two resistance (see, Table 3, A). Working on activity 2, (engaged in EIR) students have figured out that there is a two-parameter simultaneity that determines the output current (see, Table 3, D). They are also evoking a voltage-centered scenario in their explanation (MBE).

Conclusion

In this study we focused on failures and successes in science inquiry in the specific context of problem solving activities that required engagement with the NetLogo electricity models. In our experimental set up, we used two independent treatment conditions that differed in scaffolding approaches. The PF pair received cycles of *varied* scaffolding while N-PF pair received *consistent* scaffolding. Our results showed that in the case of the PF pair, the cycles of varied scaffolding resulted in engagement on different aspects of inquiry cycle; failing on some while succeeding on others. There seems to be a cumulative efficacy of cycles of failure and successes that resulted students performance in data-based explanation of the behavior of electricity models. The scaffolded experiences consistently engaged the N-PF pair in measurement activities and were successful in generating the data. However, interactions over the set of models did not engage them in all the aspects of science inquiry. We did not find any evidence of attempts at model-based explanation. The results clearly show the varied scaffolding approach to have significant potential in engaging students in various aspects of science inquiry in the context of a model-based learning environment.

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Co-Designing Curricula to Promote Collaborative Knowledge Construction in Secondary School Science

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Abstract: We describe a two-year study of a rich secondary science curriculum that was co-designed in close partnership with teachers, technology specialists and even school administrators. The goal of the research was to provide empirical support for a recent model of learning and instruction that blends the two perspectives of knowledge communities and scaffolded inquiry. A design-oriented method was employed, where the first iteration of the curriculum was evaluated in terms of its fit to the model, as well as its impact on student learning. Based on a set of design recommendations, a much more substantive curriculum was developed for the second iteration, leading to rich measures of student collaboration and deep understanding of the targeted science concepts. This paper describes our co-design process, which allowed teachers to lead the curriculum design and classroom enactment while researchers contributed design guidelines according to the theoretical model.

Introduction

It is not easy for teachers to experiment with new instructional approaches. Unlike scientists and business people who are generally motivated to embrace new practices, teachers are more cautious about change. In part, this is because the stakes are high in teaching: If something goes wrong in the classroom and things get out of control, this can have lasting consequences that make it difficult or impossible for the teacher to regain that control. Additionally, the demands of research-based approaches are often unrealistic, requiring a radical change in teachers' practices. Traditional methods such as lectures, labs and problem sets are more familiar to teachers, who understandably try to remain within their comfort zone. This is particularly the case in content-rich subject areas like science, where teachers feel a tremendous pressure to address all content expectations. Methods that engage students in high levels of open collaboration can be unconventional for teachers, who usually require time to experiment with the new methods before using them in their classrooms.

Although research has explored new ways to add inquiry-based and collaborative knowledge construction to the curriculum, these approaches are not easily embraced by teachers. For example, inquiry methods (e.g., Linn & Hsi, 2000; Edelson, Pea, & Gomez, 1996) have often been too heavily scripted and inflexible, requiring specific practices and materials that may not fit in with the teacher's existing curriculum. Another leading approach from research is that of collaborative knowledge construction (Brown & Campione, 1996; Scardamalia & Bereiter, 1996) which can be too open-ended, making it difficult for teachers to target specific learning outcomes. What is needed is a way to help teachers design and adopt rich inquiry-oriented curriculum that addresses specific science learning goals, and supports teachers and students in becoming a knowledge community.

This paper begins by considering the rich research traditions of scaffolded inquiry and knowledge communities, as well as a recent model (see Slotta, 2007; Slotta & Peters, 2008) that describes how they can be blended to create powerful new curriculum that is well suited for secondary science. We also discuss the important innovation of co-design (Roschelle, Penuel, & Sechtman, 2006), which offers a means of creating such curriculum in a way that it meets teachers' expectations while assuring adherence to the model. We discuss a two-year design study with two iterations where co-design was employed to create a technology-enhanced curriculum that was designed around the model. For each design iteration, we evaluate how well the curriculum conformed to the model, and measure the success of the activities in terms of helping students achieve a deep understanding of science in collaboration with peers.

Moving Research-Based Innovations into the Classroom

It can be challenging to implement innovations developed by "outsiders" into traditional classrooms. This is especially the case for high school science, where a high volume of curriculum content and traditional assessments make it difficult for teachers to embrace the kinds of rich inquiry and constructivist models that are advocated by researchers. Science textbooks in particular cover more topics than any other subject, resulting in textbooks that have been described as being "a mile wide and an inch deep" (Schmidt, McKnight & Raizen, 1997, p. 62). Teachers are responsible for addressing well-specified sequences of subject matter (e.g., cellular biology, genetics, human physiology), making it difficult to design learning activities where students pursue a deep understanding of science through open collaboration. Curriculum expectations more than fill up the time allotted to most science courses, leaving teachers little or no time to engage their students in discussions of "big-picture" questions or personally relevant projects. All lessons or units must fit within a tight class schedule, with outcomes that are assessable by conventional measures. Instructors must feel they are using each class period productively, and that their students are learning the science topics set forth by their national or local educational agencies. For any new curriculum to be successfully implemented, the teachers must perceive an alignment between the new materials and the mandated curriculum (Penuel, Fishman, Gallagher, Korbak, & Lopez-Prado, 2008).

Powerful Learning Innovations

There are a number of promising approaches that provide mechanisms for engaging students in rich and engaging collaborative inquiry. One common thread among these approaches is the goal of fostering knowledge creation by engaging students in collaborative activities within a community of peers. For example, in the research program called Fostering Community of Learners (FCL), Brown and Campione (1996) carefully choreographed an elementary classroom, selectively presenting materials to small groups of students with different areas of expertise so that the students and teachers within the classroom grew as a "knowledge community." Scardamalia and Bereiter (1996, 2002) have investigated a knowledge building approach where students are given exclusive responsibility for the high-level processes of knowledge construction: generating new ideas, building on classmates' ideas, and synthesizing ideas into higher level concepts. These and other innovations have the potential to transform classrooms into knowledge communities where students work on collaborative activities within their peer community. Yet, most secondary science teachers are unable or unwilling to implement such an approach in their classrooms. Methods such as FCL and knowledge building require substantial changes in teachers' instructional practices, and it can be difficult for them to make these changes while still addressing the required subject matter.

Another common theme in the research literature is that of scaffolded inquiry. Researchers have developed a number of prominent pedagogical approaches that provide students with rich collaborative inquiry activities, which often includes technology-enhanced tools and materials (e.g., Linn & Hsi, 2000; Slotta, 2004; Songer, 2006). Despite widespread enthusiasm, these approaches have yet to make any strong headway in science classrooms, as researchers have yet to determine how they can promote new cultures of learning while remaining sensitive to curriculum standards: What types of pedagogical and technological innovations are required to transform classrooms into learning communities? How can these innovations be designed? What supports do teachers need to enact new approaches in a manner that does not undermine the theoretical commitments of the design? These are all questions that need to be addressed before inquiry-oriented instruction can pervade secondary school science curricula.

Toward a New Model for Knowledge Community and Inquiry

In an effort to make headway on these problems, Slotta (2007) developed the Knowledge Community and Inquiry (KCI) model, which combines collaborative knowledge construction with scaffolded inquiry activities to target specific curriculum learning objectives (see also Slotta & Peters, 2008). The model begins with a collaborative knowledge construction activity where students explore and investigate their own ideas as a community of learners, creating knowledge artifacts that are aggregated into a communal knowledge base. An important component of collaborative knowledge construction is that learning activities (such as inquiry-type investigations) must be guided by the community itself through the knowledge construction process (Scardamalia & Bereiter, 1996). Common themes, ideas or interests should emerge, reflecting the "voice" of the community. The instructor must listen to this voice and respond by designing activities that reflect students' interests. The latter process is critical, but also pedagogically challenging to execute, since the design of any activity must also address the subject matter and learning goals of the curriculum.

It is no easy task to design curriculum that responds to community interests while addressing learning objectives and adhering to time constraints. In the KCI model, the scaffolded inquiry activities are co-designed by teachers and researchers only after the knowledge construction phase is complete, resulting in dynamic, emergent activities that build upon the themes that were identified within the knowledge base. Students then work independently or collaboratively on these activities, drawing on knowledge elements from the community knowledge base, producing new contributions to that knowledge base, and completing inquiry tasks that are directly connected to assessable learning outcomes.

Co-design: A Powerful Innovation for Classroom-based Research

How can we create instructional materials that encompass research objectives while still complementing a teacher's curriculum? The success of any research-based curriculum will critically depend on the teacher's understanding and enactment of the materials and approaches. Technology can provide scaffolding, but any new and complex method requires a complete buy-in of the participating teachers. This can be accomplished through a process known as co-design (Roschelle, Penuel, & Shechtman, 2006; Penuel, Rochelle, & Shechtman, 2007) where all instructional materials and designs are developed in close collaboration between researchers and teachers. Roschelle et al. (2006) developed co-design for a study in which they worked closely with stakeholder groups to produce an innovative curriculum for secondary school science. They describe co-design as “a highly facilitated, team-based process in which teachers, researchers and developers work together in defined roles to design an educational innovation, realize the design in one or more prototypes, and evaluate each prototype’s significance for addressing a concrete educational need” (p. 606). Co-design has a number of features that are common with other user-oriented design methods such as participatory design and user-centered design. Both these approaches emphasize the importance of input from the end users of the design innovation. However, co-design almost always involves extensive negotiations and trade-offs before any final design decisions can be made. The reliance that co-design places on teachers’ input also makes it highly compatible with design-based research.

Methodology

This study takes the form of a design-research experiment for the purpose of developing a collaborative, inquiry-based curriculum through iteration. Design research was developed by Brown (1992) and Collins (1992) in response to the recognition of the need for studying learning in context. Brown (1992) stresses that to fully appreciate the complexity of students’ learning, the researcher must study the classroom holistically. Curriculum development, assessment and the role of the teacher are all interconnected and cannot be examined independently without disturbing the synergy that is part of regular working classrooms. Contributing to a theory of learning that informs practice can only be achieved if the innovation can realistically be enacted in everyday classroom settings (Brown, 1992). Thus, design experiments have been said to “fill a niche in the array of experimental methods that is needed to improve educational practices” (Collins, Joseph, & Bielaczyc, 2004, p. 21).

Embedded Technology Scaffolds

We employed a wiki-based technology environment to support the design and delivery of all research materials. A wiki provided the ideal functionality for collaborative knowledge construction, since students could easily access and edit one another’s ideas, reorganize pages to capture emerging themes, and link pages to establish connections between related ideas. A new hybrid wiki environment improved control over student accounts, editing permissions and other features. Although it was important to preserve the open-ended feeling of collaborative editing that typifies wikis, it was equally important to have a simple, structured way for students to create wiki pages to their treatment of science concepts. The result was the development of a special web form (developed in the Ruby on Rails language) to collect metadata (using check boxes and text fields), which then generated a new wiki page that was properly linked, including pre-specified headers and the required authoring and access permissions. This web form was used in the research to create a “New Page” script (see Figure 1) that included headers and scaffolded students about specific science content to include in their wiki pages. Another advantage of the web form is that it enabled students to start working on the content right away, and gave a consistent look and feel to the wiki.

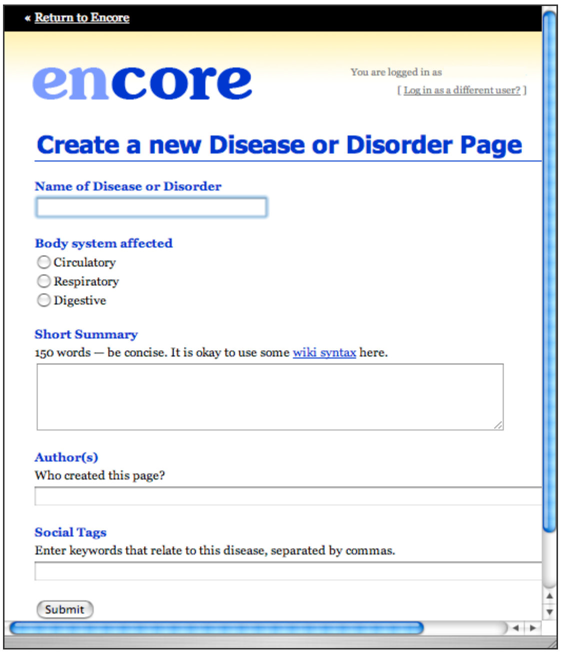

Figure 1. Example of a “New Page” Script for Human Physiology

Iteration 1: Human Physiology and Diseases

Prior to the first iteration, the researchers established a working relationship with two science teachers from a local high school. A number of meetings were held to discuss the initiation of a research partnership. In October of 2006, one of the researchers conducted field visits to observe the culture and practice of the classroom. Eight full-class periods were observed over the following three months. Beginning January 2007, the researchers and teachers met to plan a curriculum for grade ten biology students that was designed around the KCI model. Seventeen co-design meetings were held between January and May of 2007. To limit the extra workload on teachers, the co-design meetings often took place at the school at times that were convenient for the teachers. The curriculum that resulted from these meetings, the Human Physiology unit, began in May of 2007 and was one week in duration.

Participants

Participants included 102 grade ten biology students and two experienced science teachers. The co-educational school involved in this study provides specialized curriculum for high-achieving students in grades 7 through 12. Initially created as a laboratory school, this unique institution prides itself on new and innovative classroom practices. Admission to the school is competitive and based on students' score on the Secondary School Admission Test (SSAT), with 98% of new admissions being accepted from grade 6 students. The school population is ethnically diverse, with the majority of students coming from middle to upper-middle class homes. The school has a strong commitment to the liberal arts and sciences curriculum, and students are expected to fully engage in their academic program. There is a strong emphasis on community, and individual acceleration and early course specialization are discouraged. Assessment is ongoing throughout the school year and consists of formal progress reports and performance improvement plans.

Phase 1: Developing a Knowledge Base

Students began the lesson by participating in a knowledge construction activity where they first brainstormed about different diseases that affect the human body. The teacher then placed students into one of three categories of human body systems: circulatory, respiratory or digestive. In small groups, students could choose to create a wiki page about any disease of their choice, provided it was in their assigned body system. Using the New Page script, students created a "Disease Page" about their chosen system disease (see Figure 2 for an example Disease Page). This script specified some of the content that students had to include in their wiki pages (e.g. how their disease affects other systems in the human body). Students across all four class periods contributed to this same wiki repository, editing and revising each other's wiki disease pages. Each class was given two full periods to complete their disease pages, unfinished pages were assigned as homework.

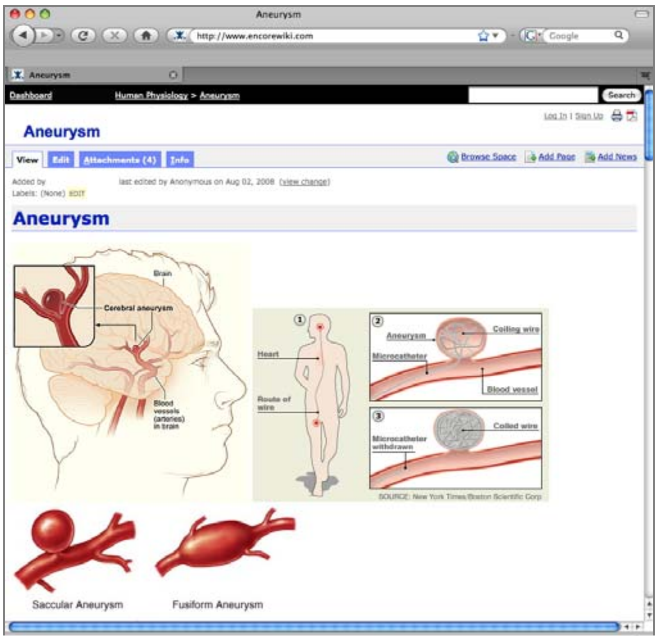

Figure 2. Example of a Circulatory Disease Page

Phase 2: Scaffolded Inquiry

In small groups, students then created a "Challenge Case" about their disease, which involved a fictitious case study about an individual who presents a number of symptoms to their physician. To engage students with the wider community knowledge base, they were instructed to solve a challenge case that was not in the same system as their wiki Disease Page (i.e. if a student created a wiki page about a circulatory disease, then they had to solve a challenge case that involved either the respiratory or digestive system).

Analysis and Findings

The curriculum was evaluated in terms of the following dimensions: its adherence to the KCI model, student learning outcomes, and students' experiences with the curriculum. The new curriculum was successful in creating a community knowledge base. Between the four classes, students created 23 comprehensive disease pages across the three systems. Each disease page was run through Copyscape©, a web-based utility that compares web pages to check for instances of plagiarism. Of all 102 students, there were four instances of plagiarism that warranted concern. When solving the challenge cases, students used their peers' disease pages as a resource. The researchers anticipated that students would use Google, but instead they consulted their community resource base. The challenge cases were solved in-class, giving the researchers the opportunity to observe students' activities.

We also compared the students' exam scores with the same teachers grade ten biology students from the previous two years, who received the traditional curriculum consisting of lectures and a lab. Only classes that had been taught by the same teacher in all three years were included in the comparison. We compared the performance of the three groups on the physiology sections of the final exam, which used similar open-ended questions for all three years (e.g., a question might ask students to describe how a disease in one body system affected the biological processes of another). An independent-measures ANOVA revealed a significant difference in students' scores. Those who participated in the wiki lesson were found to have higher scores than students from the previous two years who were taught with the regular curriculum. This difference was significant, with a value of $F(2, 96) = 7.236$, $p = .001$ (see Figure 3).

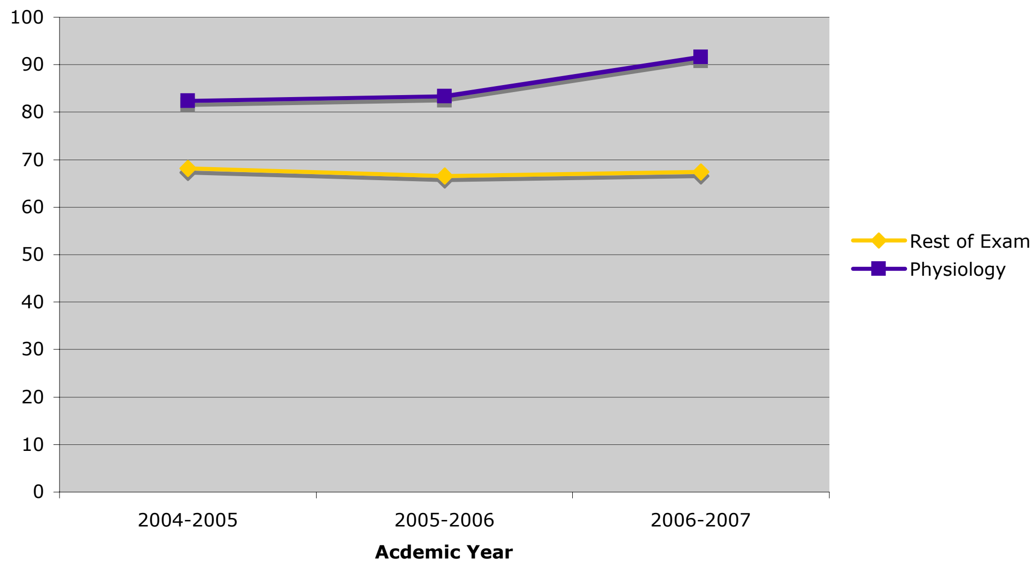

Figure 3. Students' Exam Scores

In their interviews, both teachers indicated feeling positive and enthusiastic about the new curriculum. Both teachers agreed that designing the activities were time-consuming, but that the workload was not too overwhelming. One of the teachers, Laura, admitted feeling apprehensive before beginning the unit, and expressed her concern about covering all the required material:

> We weren't going to do [the activity] just for the sake of doing it… we're very much classroom teachers. If it's not going to help the kids learn really well, we're not interested in it. But it worked. I mean, we put a lot of time into negotiating things, but I think it ended up being a really good quality lesson.

In terms of student understanding, the teachers felt that the curriculum helped students develop deeper understandings of how the three physiological systems interact together. The teachers were very satisfied with students' understanding of the material as evidenced by their responses on the final exam. The students were able to make connections between the different diseases of the body systems (e.g. how a low red blood cell count from one disease could make a person more susceptible to a disease in a different system). The second teacher, Joanna, described how the curriculum was able to address the content standards: "When I was doing my marking, I was actually pretty surprised… with this lesson they definitely covered the [Canadian Education] Ministry content, and they ended up learning a lot more about how the different body systems interact." One student demonstrated such understanding in a post-study interview:

> "If there's a problem with the production of red blood cells in one system, oxygen won't be transported around the body very well, and CO_2 will not be removed as efficiently. The disease wiki showed me that there's a direct link between the processes of organelles and how they work in our body – like the mitochondrion O_2 go through the Krebs cycle, and red blood cells bring the O_2 to the other cells for use in cellular respiration."

Design Challenges and Recommendations

Although the first iteration of the curriculum was encouraging, a number of problems became apparent during its enactment. During the scaffolded activity, students were successful in using their community resource (i.e. the repository of disease pages) to solve their challenge cases. However, when doing so, they did not engage deeply with the material. Students only needed to consult their peers' wiki pages briefly to solve the cases, there was no cause for them to make connections to the material or extend it. Because of this, the design did not meet the definition of the KCI model, which requires a deep interconnection between the scaffolded inquiry activities and the knowledge base created by the students. Future iterations would need to make such connections more explicit by scaffolding them. Additionally, a number of students expressed disappointment in their interviews that the disease pages were not formally graded, and felt they should have been rewarded for their efforts. Many students also expressed annoyance at not receiving more explicit and direct instructions about creating a disease page. In the words of one student:

> "I thought we were going to get a rubric for this assignment that we did, why didn't we get a rubric? All we got were a few comments about what to include in the wiki, how are we supposed to know what to write without a rubric? How are we supposed to know what to include? And the whole wiki thing was worth 5% of our final grade – that's a lot, considering we were only given two class periods to work on it."

Taken together, the data from the first iteration illustrated areas in which the curriculum needed improvement. A number of refinements were needed to meet more of the researchers' objectives (e.g. having students make deeper connections to the community resource). The curriculum also appeared to require longer activities for which the teachers could assign grades.

Iteration 2: Canada's Biodiversity

The second iteration of the KCI curriculum was implemented in the fall of 2007 with a new cohort of 114 grade ten biology students. The co-design team remained the same, with one additional science teacher joining the group. The school principal and vice principal also attended a small number of these meetings. The curriculum content for Iteration 2 was Canadian Biodiversity, and included a section on practices for sustainable living. The KCI curriculum in the second iteration was interspersed over a much longer period of eight weeks.

Phase 1: Developing a Knowledge Base

The teacher began the Biodiversity lesson by placing students into one of eight Canadian biome groups. Working in these groups, students were free to choose a geographical region from Canada for which they would create a wiki "Ecozone Page". A small number of groups wrote a wiki page about a biome instead of an ecozone. A New Page script was also used in the second iteration, and specified content that was outlined in the curriculum standards (e.g. eubacteria and archeabacteria in ecozones). Once again, students across the four classes contributed to this same wiki repository, adding to and editing their peers' ecozone pages. Over the eight-week unit, students were given a total of six full class periods to complete their disease pages, with unfinished pages assigned as homework.

Phase 2: Enriching the Knowledge Base

In pairs, students then created a "Biodiversity Issue" page. A biodiversity issue page described a problem or issue that was threatening one of Canada's ecozones. Students were able to utilize their expertise by choosing a biodiversity issue that involved the same region for which they had created an Ecozone Page. Similar to the Human Physiology lesson, a wiki template specified content to be included in the Biodiversity Issue pages (e.g. the importance of reestablishing or preserving the biodiversity of an ecozone). Since ecozones and biomes overlap geographically, students were asked to make connections between regions, including how the biological factors of one ecozone can influence the biology of another. Students were also asked to include links to any of their classmates' wiki pages that they referenced.

Phase 3: Identifying Emergent Themes within the Knowledge Base

Efforts were made in the second iteration to ensure the curriculum reflected the voice of the community. To this end, a "critical juncture" phase was added to capture students' interests and incorporate them into the KCI curriculum. After the Biodiversity Issue pages were completed, the researchers and teachers met to review the content and identify students' interests as represented in their wiki pages, with the purpose of incorporating these interests into a subsequent activity. Five major themes were identified: (a) habitat loss and destruction, (b) invasive species, (c) climate change, (d) pollution, and (e) demands of growing urban populations. These five themes were used to guide the design of the final phase of the curriculum: a scaffolded inquiry activity where students wrote an individual research proposal.

Phase 4: Scaffolded Inquiry – The Individual Research Proposal

The purpose of the individual research proposal was to engage students in making connections between the ideas and concepts in their community knowledge base (the ecozone and biodiversity issue pages), and pressing real-world problems, including the implications for Canada and their local school community. Teachers asserted that the activity needed to be an individual to allow for the assignment of an individual grade within the biodiversity unit. In this activity, students were asked to write a research proposal that outlined a current environmental problem in Canada, including a detailed plan of how to address and remedy the situation. Students were asked to connect their proposals to as many ecozone and biodiversity pages as possible, including links to all referenced pages. A New Page script specified aspects to be included in their proposal: project summary, biodiversity impacts, biodiversity specifications and possible root cause.

Analysis and Findings

Similar data were collected in the Biodiversity curriculum as that collected for Human Physiology, with the addition of web logs of students' wiki activity. Across the four classes, students created 34 ecozone and biome pages, and 47 biodiversity issue pages, and were actively engaged in revising the wiki entries of their knowledge resource. Figure 4 illustrates the number of page revisions for each ecozone (i.e., each time a page was opened and saved) vs. the average number of words that were edited in each revision. We created an algorithm that parsed the wiki data for text that had been added, deleted or revised, excluding any text found in wiki mark-up, image tags or title headers. We found a significant positive correlation between the number of word edits and the number of page revisions ($r(35) = .90$, $p < .0001$) suggesting that students were actively authoring throughout the Biodiversity unit, rather than continuously formatting their wiki or working on aesthetics.

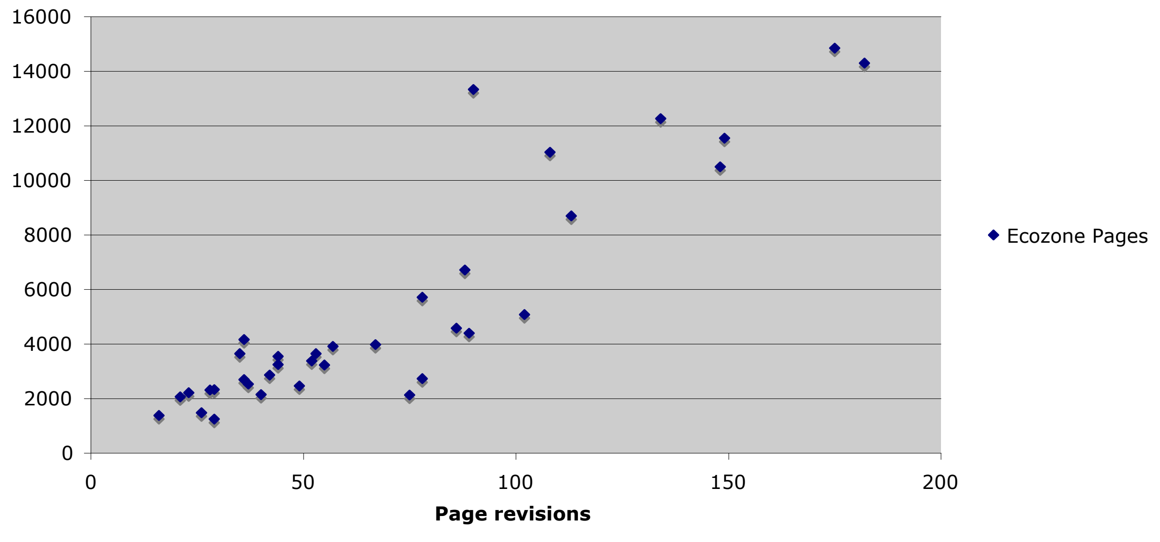

Figure 4. Ecozone Page Revisions by Average Number of Words Edited

Student work during the knowledge construction activity also appeared to have a positive effect on learning outcomes. Using the two classes that were taught by the same teacher, a correlation test was performed on the relationship between students' exam scores and their ecozone page evaluation score. Student work on the ecozone pages were evaluated in terms of the specific biology content that was included in the wiki. Ecozone pages that included the content specified in the New Page script were awarded higher grades. The teacher also assessed the pages in terms of accuracy and completeness. There was a significant positive correlation between the Ecozone Page scores and the biodiversity exam scores ($r(49) = .38$, $p < .0056$), including much overlap between students' scores (Figure 5).

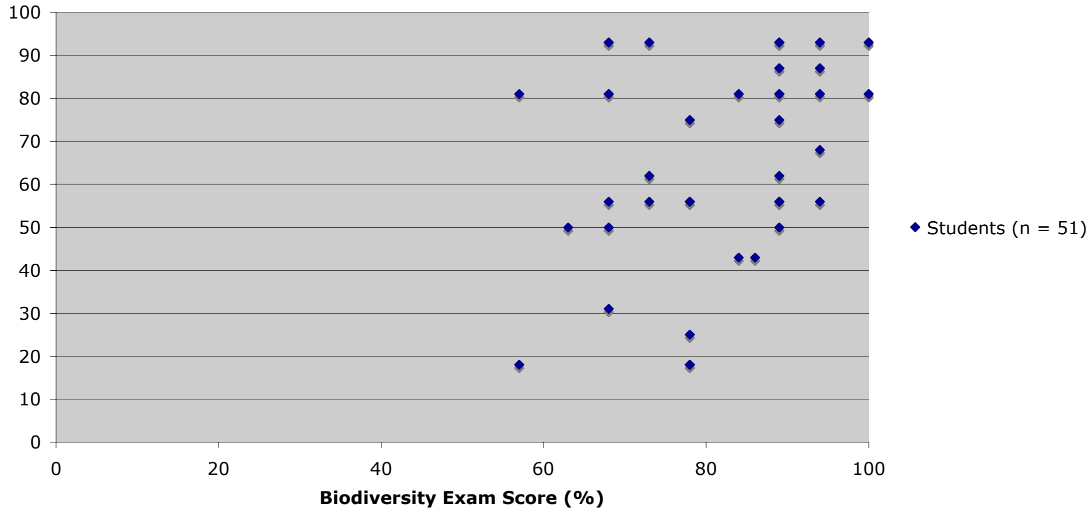

Figure 5. Students' Biodiversity Exam Scores vs. Ecozone Page Scores

During their interviews, students revealed mixed reactions towards the KCI curriculum in terms of its presentation and structure. While some students appeared to enjoy the open-ended format, others felt it interfered with what they described as "regular" learning. Lila described her perspective as follows:

> "[The new curriculum] isn't fair because some people don't work well like this. They work well when they're given a lot of questions and they have to basically learn the material first and then be tested on that and everything. And also, I think regular learning is better because then you have a direction to go into, like you know what you want to look up. And then once you have the background information on the topic and everything I think it's easier for you to think of more questions and, like, analyze the whole situation."

Other students were more positive about the open-ended aspect. For example, Jonah enjoyed being able to discern his own topic instead of being "just told what to do all the time". Ingrid felt similarly, but she also explained that she enjoyed the inquiry of learning about ecozones and other environmental issues. In Ingrid's own words:

> "Let's say you're starting off with a question, like why are forests in British Columbia decreasing right now, right? From that you could go on and you discover a whole bunch of other questions. And then from that main question you can maybe go on to investigate the disappearance of the spotted owl or something. Which is linked to the forests. So it's kind of like a linkage process instead of just being like tested on one set goal, and it's also more interesting to find you own way."

Part of the value of the KCI model is its flexibility in terms of subject matter and teacher enactment. Since co-design ensures that teachers are deeply involved in the design of the materials, the researcher can remain hands-off when it comes time to enact the curriculum. As teachers become more involved in co-design, their understanding of and familiarity with the KCI model will increase. An interview with the school vice-principal revealed his position on the research-based innovation within his school:

> "The important thing for me is if we're going to introduce a new intervention or technology, then it needs to be sustainable. Because in the beginning I think the researchers have more with the technology, but now our teachers are getting there, too. They're more confident and comfortable using it, and now they're enabled to a point where they can do a new curriculum and sustain it, and share it with their colleagues. If this falls apart because it's totally dependent on the researchers to make it work, then there's not much value in it for us."

Design Challenges and Recommendations

A number of challenges arose in the Biodiversity curriculum that were not present in the first iteration. Although the one-week duration of the Human Physiology curriculum appeared to be too brief, the eight-week period of the Biodiversity curriculum was too long. In particular, the number of co-design meetings required throughout the design process proved to be too much for the teachers, even though the researchers were very obliging. Adding a third teacher only contributed to the difficulty of planning meetings throughout the term. Since the teachers had varied school schedules, it was not possible to meet during class time. Meetings that took place over the lunch hour were often interrupted by students, or were truncated so teachers could use the time for marking or class preparation. One of the teachers, Laura, described her experience of the second iteration as follows:

> "It was really hard to make the meetings. Really hard. There had to be an outside force telling me we need to meet. And it had to be me saying if we don't meet, I'm shafting somebody's research. And so many times I was dragging my heels thinking 'I have so many more important things to do'. But those meeting were really important. And they were essential to making this work."

The eight-week curriculum also extended the length of the knowledge construction phase, which ended up being problematic. In the first iteration, students' work on the disease pages was limited to two class periods over the course of a week. In the Biodiversity curriculum, the combination of Ecozone pages and Biodiversity Issue pages resulted in too much "busy work". Both students and teachers felt overwhelmed with the amount of content that was generated in the wiki. Future iterations of the KCI model will need to find the middle ground in terms of the ideal length for a knowledge construction activity.

Conclusion

This research provides support for the Knowledge Community and Inquiry model, in which scaffolded inquiry activities provide students with incentive and opportunity to make use of their community knowledge base. The co-design method was effective, and essential for helping teachers feel committed to the curriculum. This commitment from teachers was necessary to ensure that students were engaged with the materials and actively participating in the activities. The KCI model also enabled the teachers to adopt new methods of knowledge construction and collaborative inquiry, which were described by the researchers but could only be enacted by the teachers. We see our growing partnership with the teachers as step towards the "hybrid" culture described by Bereiter (2002), in which the culture of researchers and teachers come together to address educational concerns that require the expertise of both groups. In our research, the teachers responded enthusiastically to the new methods, and are currently engaged in designing a new global climate change unit that is a further extension of the KCI model. Moreover, they continue to enact the physiology and biodiversity units, which have become a staple part of the biodiversity curriculum.

This study demonstrates that knowledge community methods, when developed in collaboration with teachers, can be successfully designed for high school science classrooms. Although still ongoing, this research lends support to the KCI model as a powerful mechanism for embedding collaborative knowledge construction into curriculum activities. This work thus responds to an ongoing challenge of how to make community-based learning activities and scaffolded inquiry more relevant for secondary teachers, and opens up possible avenues for future research and pedagogical models.

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Forums for preservice teachers' development: Lessons learned from five years of research

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Abstract: The CALICO research network, which includes four research laboratories and six teacher training institutes, is devoted to the study of forums in postgraduate education. Among the numerous studies the research network has been performed, the case of preservice school librarian teachers is notable. Since 2002, two training institutes (Caen and Rouen) have shared an e-learning platform which fosters hybrid formation situations based on exchange, mutualisation and collective work. For the past 5 years, significant research has been undertaken in order to better understand the organization of such forums, the activity of participants and groups, and the evolution of discourse and so on, involving very different tools and methods. This text provides a guided tour of these research efforts, explaining their importance and putting the main results obtained into perspective. It is a step towards a better characterisation of the role and nature of the various forums used during training sessions.

Introduction

International research on forum in education is very active and many debates are currently open. In the following text, we have decided to skip general references due to space limitations and focus on the presentation of a five year research effort. This research work, part of the CALICO network, focuses on collaborative activities, specifically discussion forums as a part of general training. We study a very specific kind of forum: that which takes place in a hybrid organization. In our work, we use an open forum in the framework of case studies, inspired by Casenet (Baron et al., 2001), now called Casenex. A narrative of a professional problem, met at school, is given online. This narrative is analysed and discussed during a three-week period between the trainees from Caen and Rouen via a forum.

In his review of asynchronous discussions in higher education, Hammond (2005) distinguishes several types of forums. A forum is a mere technical device that is given meaning by the context at large in which it is used. Since each forum has its own characteristics, it is not wise to derive general results without paying great attention to specific features (Bruillard, 2007). For example, the forums we study include no question/answering posts and are mainly focussed on collective discussion and collaborative exploration of issues.

The forums we study have several common features: a short time (3 weeks), between 20 and 30 trainees from two different training centres, and between 40 and 124 messages per forum. The collective exploration of a professional problem allows the comparison of the personal trainees' experiences and personal views. During the forum, the trainees' language level is similar to the language level when they are physically together at the training centre: standard French, a proper, accurate and respectful language style. Humour and irony sometimes occur, and within the general topic digressions are rare. Their discourse is a professional training discourse. The trainers rarely interfere in the discussion. Their messages are mere suggestions for reflection, requests calling for reformulation, or regulation messages.

Five forums held between 2002 and 2006 were analysed according to different research points of view. One forum in particular was studied by different researchers. This study ran from 2002 to 2008 and addressed the participation, production context, dynamics of the text, or discourse analysis. We use automatic, semi-automatic or manual methods. When adopting a research perspective, combining these analyses can help to better understand the overall dynamics of exchanges and the way a collective reflection is elaborated. When adopting a trainer's point of view, we also tried to identify the elements of this collective reflection and how the trainees assess their professional development. To put the results we obtained and the research methods we adopted into perspective, we used a chronological order.

Step 1: The participants' engagements; counting and visualising, interviews

The aim of the first research work was to understand the trainees' activities, participation modalities, engagements, and difficulties (Fluckiger, 2005). The number of messages gives a first characterization. The observation of individual variations of participation, of inter-individual variations, and of chronological variations participation features has revealed strong differences in the temporal and inter-individual order and shows a heterogeneous and irregular participation. In order to understand the reasons underlying such behaviours, training assessments and interviews with researchers (Harrari and Rinaudo see Baron & Bruillard,

2006) reveal the trainees face three main obstacles: readability problems (to understand the exchanges' structure was difficult and has been an obstacle for participation), technical and material constraints (computer or internet connection access), and a neglect of exchanges via forums due to lack of time or multiplicity of activities.

The chronological presentation below (*fig.1*), which includes dates and threads, allows us to observe individual participation without losing a global view of the forum. A phenomenon is therefore underlined: those who have posted two or more messages dispatched them on several threads over a very short period of time.

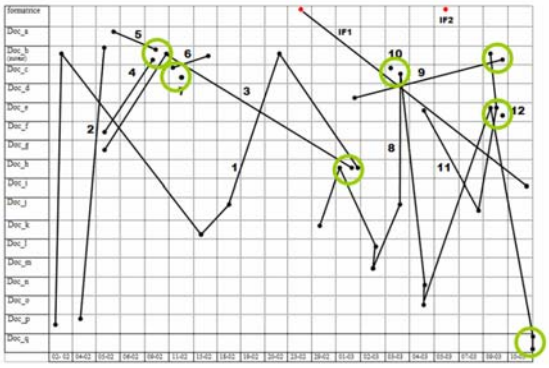

Figure 1. Messages each day with posters and threads (Fouénard, 2004). The green circles indicate moments when some participants sent several messages in different threads.

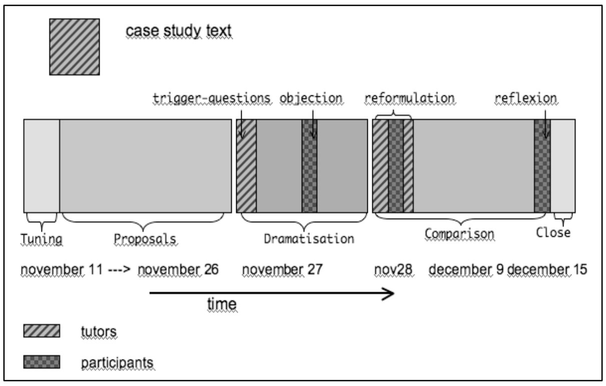

Figure 2. A discussion forum seen as a collective discourse, with the main moments and significant shifts marked according to the origin of the posts (Lucas, 2005)

The users tend to optimize their time, posting several messages the same day in several discussion threads, returning to the forum only later. Fouénard (2004) called it *punctual pluri-participations* and Fluckiger (2005) a *blast* mode. Among the 38 messages of this forum, 17 were posted in a *blast*.

There are several ways to interpret this phenomenon. The forum system used for the case study is BSCW. It is a very good product for distant collaboration however it is not well suited to forum discussions. There is no possibility to access directly to the whole arborescence of messages, only the title of each thread is directly readable. So, students had to open all the threads to be informed of the different messages. Another explanation is the opportunity to participate as little as possible to eliminate an imposed exercise.

Participants' engagement: perceived activity

To understand the trainees' activity, we must also consider the actors' feeling. This information is not available in forum contents. Therefore, several interviews have been organized with the participants (Fluckiger, 2005), (Harrari and Rinaudo in Bruillard et al., 2006). They give interesting hints about the way the trainees organize their work.

Their discourses indicate very different practices oscillating between two extreme positions. Some declare little participation and confess they read the messages only near the end of the activity period. Others claim they are more engaged and contribute throughout the forum activity, sometimes in the evening or during the week-end. Beyond these opposite attitudes, to use forums with a group that has the opportunity to discuss regularly face to face does not seem obvious, even if they admit it is a good way for brainstorming. According to the trainees' interviews, forums are considered a scholarly activity. Interviews also revealed a strange result or an apparent paradox. Forums seemed to be useful to those who had the opportunity to meet every week (a means for additional exchanges), but less useful to distant group (Caen and Rouen). Distant communication via forums (more generally an e-platform) seems to reinforce group cohesion, excluding the other group. This fact has been confirmed by the interviews.

Step 2. What happens during forum time?

Distant work via forums can appear to be a constraint for the trainees, and they do not immediately perceive the purpose of the activity. However, trainers consider forums to be a key element in their students' educational strategy, because they provide a good material for later face to face work. So we have to find elements inside the content of the texts to understand their running better.

The exchange dynamics

A chronological reading of the forum messages shows interferences between the exchanges because of the *blast effects***:** their thematic unity does not exactly fit the discussion threads. A lexical analysis (Clouet, 2005), when counting the occurrences in the same lexical fields, points out that the role of forums is to mobilize ideas and filter them. The most technical subjects are progressively dropped out for more reflective exchanges. The forums seem to achieve a progressive sorting out among the proposed ideas. The overall discussion seems to produce a kind of maturing of exchanges and a progressive appropriation of the proposed issues by the group, allowed by a sufficient time given to forums.

This evolution of contents indicating the cognitive aspect of the forums is demonstrated by a discursive analysis using *Themagora* software, which shows the hierarchy of thematic units. Considering a forum as a whole account, the study (Lucas, 2005) has investigated the different levels of organisation in order to point out their structure. Several periods can be distinguished and divided into “moments” *(fig.2)*, each of them marked by different intervention modes: short impersonal interventions, longer interventions with more accurate position taking, and personal experience stories. These moments are named “exploration”, “discussion”, “dramatisation”, “comparison” and “enclosure”. They organize the macro-structure of the whole text. Some particular messages seem to have a structuring discursive role, bringing dynamics and depth. The forum is thus a collaborative story, the arguably unconscious product of a harmonisation of monophonic voices aiming at a collective discourse.

A typology of messages

If some posts seem to play a specific role, providing depth and dynamics to collective discourse, it is important to identify their characteristics. A graphical representation of three threads (Bruillard et al., 2006) derived from different forums held in 2003 helps to spot each message and identify the interlocutors. In correlation to the interviews run by Harrari and Rinaudo (2006), another feature appears: the existence of subgroups exchanging together in a privileged manner and expressing themselves at specific moments. The characterisation of the messages coming from these different groups has been achieved through their content, structuration, lexicon, and enunciation. It leads to a typology including three kinds of messages.

Arising during the first half of the thread, most often at the beginning and seldom at the end, short messages (3-8 lines) promote the sharing of experiences and mainly describe attitudes, ways of doing things, specific practices limited to the school in which they work.

Another group of trainees give their preference to a different kind of message which appears during the second half of the forum. The length of these messages varies from 6-8 to 20 lines and their content is varied: professional positions taken in opposition to previous messages, a synthesis of the preceding messages, proposals at a generic level, messages with didactical intentions or explorations of different facets of an issue. These messages include conclusion paragraphs. Accounts of experiences are followed by a professional comment. The students’ discourse gives evidence of their capacity to hold their practise at a distance. The strong presence of the “I” pronoun shows the authors are actively involved in their assessments. These messages are said to indicate a deepening of reflection and help the structure of the forums evolve. The new orientation they give to the discussion promotes messages of the same type or messages of type 3. These messages appear in the second half of the forums and are of medium length. They approve or back a type-2 message with an example from their lived-experience. Unlike the type-1 messages, these messages are not limited to testimony. The accounts are ended by an opening (the exposition of a similar problem), a question, or a counter argument.

Step 3. How to account for what is learned?

Since the overall dynamics of forums speak to their cognitive function, it is important to recognize their learning gains and discuss how these gains are made. Through the rhetorical dimension of speech, forum contents can indicate how novice teachers express their professional situation and can give an image of their current professional identity. Therefore, on three other forums (2004-2005), we studied how discussions foster the construction of professional identity, individually and collectively, and how they display this process at the same time. We were interested in determining how the trainees express, through discourse, their relationships to the institution, their place in the educational system or in schools, their present evolutions, and their professional positions (Clouet & Roué, 2007). Our general theoretical framework refers to textual and discursive linguistics, an "extremely polymorph", multi-dimensional and "eclectic" approach (Kerbrat-Orecchioni, 2005).

A lexical approach

The lexicon shows how the process of professional affiliation takes place and what social representations novice teachers have on their profession. Two kinds of lexicons are studied: a professional technical terminology (corresponding to their speciality as librarian teachers) and a standard educational vocabulary.

The trainees’ technical vocabulary has been compared to a reference lexicon which was elaborated by extracts from texts written by professionals of the domain. The number of professional utterances amount to 5% of the online discussions. These words mainly refer to the technical aspect of the work. The trainees use a general vocabulary that is relevant to the topic and corresponds with objects, tasks, or precise concepts. The lack of requests for word clarification demonstrates an in depth-understanding of this professional terminology.

If the technical vocabulary is rather steady and relevant, the standard words shared by the educational community are polysemous and subject to different interpretations. This lexicon seems to be of greater interest. This terminology covers several varied fields, related to pedagogy or ethics. It belongs to the usual vocabulary used to exchange experiences and name actors, context, and action.

To study this vocabulary, we made a systematic inventory of the words used, mainly nouns, nominal collocations, and verbal collocations. The comparison of synonyms (or terms of close meaning) referring to a same piece of reality is significant of different points of view. The variations, for example in the use of synonyms to call the pupils (“pupil, child, reader”...), reveal changes in the positions adopted by the trainees. At times they act as teachers, while at other times they act as educators, school librarians, even parents. The way the novice teachers designate themselves (“documentalistes” or “professeurs-documentalistes”) and others (“colleagues, teachers”) reveals the challenge to find their place in the educational institution, define boundaries, and position themselves in various communities.

On another hand, the comparison of verbal and nominal collocations shows that common references are stated by the group and never discussed. Although it is difficult to evaluate to what extent these references are internalized, one can list a considerable amount of shared values (“respect”, “laïcité”) and professional ethics. By the means of online discussions, young teachers legitimate themselves and build a positive image of themselves and their profession, an ideal image (“responsibility”, “work in team”). On the other hand, shortcomings and approximations of the topics discussed can be evident. A discussion forum underlines what is "already there", the knowledge young teachers have acquired through previous experiences, and fosters its formalization through exchanges, allowing individual implicit knowledge to merge into conscious shared knowledge.

Enunciation

Enunciation refers to the relations the speaker weaves between himself and the discursive context, between himself and reality. Through linguistic units such as modalizing terms, evaluating items, and shifters, the speaker inserts himself in the message and evaluates its content.

The trainees, especially at the beginning of the year, rarely use the possessive adjectives “my/our” when speaking of people. They mainly use generic expressions such as “the students/ the colleagues” referring to abstract and undifferentiated individuals, indicating their weak integration in the school context. The interpersonal relation is slowly constructed and eventually, the geographical background is incorporated (“my secondary school”).

The trainees use impersonal structures and verbs in the infinitive (70% of the listed verbal collocations), which conceals the speakers’ presence (Clouet & Roué, 2007). These structures express strong beliefs, virtual potentialities, desires, and evident truths not to be discussed or negotiated. The world seems to be presented straight away and objectified: the text of the forums appears as a « multiple voice », that of an abstract, undefined and polyphonic speaker voicing good sense and shared knowledge (Vion, 2001).

At the beginning of the year, the trainees’ discourse is a general one, unlinked to the school context. Later in the year, however, general opinions and principles tend to fade away to the benefit of precise observations of reality and more personal statements in the first person singular. The texts of the forums are ready snapshots of the technical knowledge internalized, the shortcomings and inaccuracies, and the skills being developed (interpersonal relations and the progressive account of the reality of the school context). The young trainees’ discourse speaks for a gradual affiliation to a status, subject, and corporation.

Table 1: Three ways of developing a discussion and constructing shared reference

A joint construction by juxtaposition or agreeing collaboration	A co-construction through adjustments	Construction by direct confrontation
Building up, step by step, by expanding with consecutive sequences without cancelling the previous ones No logical or hierarchical relation Each message controls and reinforces the previous ones Evidence becomes a mutually shared and acquired reference	An exploratory approach Looking for a mutual solution without any antagonism or disagreement Thinking goes on without any interruption, through regular and consecutive adjustments Requests which call for clarification Assertions with modal variations which express doubts or uncertainty	Argumentative sequences in a more polemical and rhetorical way Aims at convincing, persuading and getting the others’ agreement A definite personal point of view Claims with arguments, counter-arguments, guarantees and backing Parts of forums, sometimes mere threads

Three ways of developing a discussion and constructing shared reference

During discussions, young teachers construct a mutual reference through discursive sequences: they investigate professional problems, state viewpoints, debate, test solutions, express values... So how do forums evolve? We have highlighted three processes.

In the three cases we have examined, the discussion threads are not closed and could seem incomplete. Nevertheless, it is clear that in the first two cases (construction by juxtaposition or by adjustments), the forum reaches an explicit consensus. Once negotiation is concluded either by exhaustion of the topic or by mutual agreement, its issue becomes acquired knowledge which will not be discussed again. Alternatively, in the third case, a consensus is not reached. The discussion is not finished; the opposite claims are still competing.

As long as the forum continues, the pieces of the newly constructed knowledge are scattered through the messages. Professional knowledge is neither formalized nor synthesized, which is one of the limits of this type of discussion. Therefore it has to be given a name, developed, formalized which will be one of the activities when the teachers are face-to-face at the training centre afterwards.

Perspectives

Forums play a double role: (1) they offer a rich material to explore, giving snapshots of the situation at a given moment in the professionalisation process; (2) they help to construct a collective professional identity through collective discussion. During the preservice teacher development, forums can provide useful information to trainers. The results and research tools giving indicators and visualisations are of great importance (Bratitsis & Dimitracopoulou, 2006; 2007). Moreover, as our forums are very specific, it appears that new indicators may be given.

Moving forward, we will try to confirm the existence of invariants on other forums and to enrich the different analyses we have done until now. As the Calico research network provides tools available on the web, we will use them. It is therefore necessary to expand the reference lexicon, and to design an organization of this lexicon. To give feedback to the participants, as many researches do, will be initiated and we will analyse its impact on the debates to come. Finally, we will put our results into perspective with what has been observed in other forums, in order to obtain a sort of taxonomy of forums and associate invariants to ideal types of each category (Bruillard, 2007).

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Online Discussion Design on Adult Students' Learning Perceptions and Patterns of Online Interactions

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Abstract: This proposal reports a study examining the impact of the online discussion design on adult students' perceptions of online learning and their online interaction performance. Specifically, in this causal-comparative study we collected data with surveys and the content analysis of online discussion scripts to explore the learning impact of online discussion types (instructor-led versus student-led), the discussion grouping design (class-wide, group discussions, versus the integrated), and the computer-mediate communication (CMC) environment (asynchronous versus hybrid). The study indicated that the online discussions that were student-led and integrating class-wide and group forums predicted higher learning satisfaction and deeper learning for adult students.

Introduction

Research on higher education has been predominantly based in historical perspectives, beliefs, and curriculum of a traditional student profile – of a person who is 17-24 years old (Kasworm, 1990) living on or near campus. Contemporary online student populations diverge significantly from these student profiles and experiences. Particularly, "most distance education students are adults between the ages of 25 and 50" (Moore & Kearsley, 1996, p.153). These students exhibit significant differences in academic, psychological, and life involvements from traditional students (Richardson & King, 1998; Schlossberg, Lynch, & Chickering, 1989). Corresponding to adult students' learning profiles, certain online teaching design interventions have been speculated. However, few in-situ studies have been conducted to examine the application of these speculations.

Studies of the designing factors of online discussions that affect adult learning are especially sparse. Recently, learning is conceptualized as a participatory social process where multi-stranded interpersonal transactions mediate the exchange of knowledge (Cole & Engestrom, 1993; Moll & Greenberg, 1990). In such a context, online discussion has become a prominent strategy used in online education to honor the need to learn in socially negotiated spaces (Berge, 1997; Ke & Carr-Chellman, 2006). Thus, online discussions among adult students become an increasingly common and important phenomenon for attention and research.

A recent review of online discussion studies indicated a variety of instructional interventions, including mainly group structure, mentoring and scaffolding, and argumentative instruction (Spatariu, Quinn, & Hartley, 2007). On the one hand, the current state of online discussion research discusses mostly theory but provides little empirical evidence. On the other hand, the research results are based mostly on laboratory experimental studies or surveys, which exclude the authentic context of online learning.

Different from prior research, this study empirically investigates two designing factors of online discussions that have not been well-addressed in empirical studies – discussion types (instructor-led versus student-led) and grouping design (class-wide versus group discussions) in the natural setting of 10 online courses. As Mazzolini and Maddison (2003) questioned, when facilitating online discussions, should online instructors take a prominent 'sage on the stage' role to lead online discussions or a more constructivist 'guide on the side' role for students to lead the discussions? Although the review of online discussion literature seems to suggest a predominant view of online instructors as more a 'guide on the side' or a facilitator (Blignaut, & Trollip, 2003), few empirical studies are available to validate the advantage of student-led online discussions over instructor-led ones.

Similarly, although group size is sometimes discussed in the discussion-based online learning literature, there is relatively little empirical research on this issue. Anecdotal advices exist. For example, Rovai (2002) suggested there should be a trade-off between having enough members to support lively discussions and not having so many participants that people feel overwhelmed. Dooley and Wickersham (2007) expressed concerns that lower level of critical reflection and deep learning would occur in the whole class discussion that in smaller, group discussions. However, more empirical evidence on the relative effects of class-wide discussions versus group discussions needs to be found to back up these advices.

In addition, the current study examines the impact of the computer-mediate communication (CMC) environment, a technological dimension of the online discussion design, on online adult learning. A recent review of the literature indicates that the majority of research on online discussions has been conducted over asynchronous CMC tools; few studies have been done on online discussions in a hybrid (integrating asynchronous and synchronous communication tools) discussion environment and even fewer research projects have been designed to compare hybrid and asynchronous online discussions. Nevertheless, with the improvement in CMC technology and the availability of affordable synchronous CMC tools (e.g., two-way web conferencing systems), it is critical to conduct research to compare an asynchronous communication environment and a hybrid one in their effects on students' online learning, especially that of adult students. Due to decreased attentional capacity and working memory, older adults are particularly prone to task disruptions when they are required to perform two or more tasks simultaneously (Sit & Fisk, 1999). Therefore, a communication tool that requires multitasking (such as text-based chat) may create cognitive overload for older adult students. In other terms, a hypothesis is that an asynchronous-only CMC environment should benefit adult students more than the one that integrates synchronous CMC tools. This hypothesis needs to be examined in empirical research.

Online Learning for Adult Students

When reviewing representative adult learning theories, Cercone (2008) synthesized that high-quality online learning for adults need to emphasize self-direction, connecting new knowledge to past experience, and self-reflection – in other terms, deep learning (Majeski & Stover, 2007; Moon, 1999). In agreement with these scholars, this study adopts deep learning theory as a foundation framework that defines successful online learning for adult students. According to Moon (1999), learning as a continuum ranging from the stage of *surface learning* where the learner simply memorizes new ideas to deep learning where the learner actively integrates new ideas into cognitive structure through learning in a social negotiation environment. Correspondingly, Fink (2003) conceptualized the deep learning to include the major components of integration (connecting ideas), application (applying concepts and skills to an actual problem), and human dimension (learning about oneself and others).

In addition, *deep learning* for adult students indicated that successful learning should engage the whole person – cognitively, socially, and affectively – in the learning process (Fink, 2003; Garrison, Anderson, & Archer, 2001). Driving from the *deep* learning theory, interactivity in the class participation and collaborative learning are the two key elements of online learning, critical to student success and satisfaction (Frey & Alman, 2003). Hence adult students' online interaction performance becomes a key indicator of their cognitive learning outcomes (Garrison, Anderson, & Archer, 2001). Then, according to social constructivists of online learning (Gunawardena, Lowe, & Anderson, 1997; Rovai, 2002), social presence refers to the ability of individuals to project their personal characteristics into the community, thereby developing a sense of community toward their peers in an online course.

Method

In this causal-comparative study, quantitative data was collected with surveys and the content analysis of students' online discussions throughout a regular school semester. We conducted inferential statistics to predict causal-effect relationships between the online discussion design (comprising the discussion type, the grouping design, the computer-mediate communication (CMC) environment) and online students' perceptions and performance.

Courses and Participants

Fifty one students, majored in nursing, business management, and education were recruited from 10 web-based courses (three are undergraduate-level and seven graduate-level) in an American research university. These courses had the following features: 1) all courses were offered purely online using WebCT course management system; 2) adult students were the majority in every course; 3) all courses were taught by experienced instructors (with averagely 5 years' online instruction experience); 4) five of the ten online courses employed hybrid CMC tools (threaded discussion forum, chat room and/or Live Classroom web conferencing system) to support online interaction activities while the other five only used threaded discussion forum; 5) the ten courses differed in their online discussion types and grouping: Five courses' online discussion types were classified as student-led and five as instructor-led based on the course instructors' self report and an expert review of online discussions[1]. Five courses had only class-wide discussions, three had only group discussions, whereas the other two had both.

In this study, adult students are defined as a student who is older than 25, returning to or re-entering their post secondary education and enrolling on less than a full-time basis. Participating students' demographic data, including age, gender, ethnic status, and perceived technology competence level, was collected prior to the study. The participants were diverse in their educational levels: 16% undergraduate, 58% master students, and 26% doctoral students. The age range of the participants was 24-59, with 43 as the mean, 22% younger (24-29), 48% mature (30-49), and 30% older (50 and above). 28% of the participants were minority (Hispanic and Asian), 85% were female, and 14% rated their confidence level as "basic" or "below basic" in the use of technology to complete coursework. And there was no significant correlation between students' age and their confidence level in using technology for online learning.

Data Collection

Procedure

The examination of participant's online interaction performance was conducted through a content analysis of archived online interaction transcripts (i.e., threaded online discussion posts). Online interaction transcripts throughout the whole school semester were archived. For the reported study, averagely six weeks' online interaction transcripts were gathered and coded for each course (two at the second and third school week, two at the mid-term, and the other two at the end of the school term).

At the end of the school session, three quantitative surveys were distributed to all participants to measure their learning satisfaction and attitudes toward learning environment, self-perceived online learning stages (*Deep* vs. *Surface* learning), and perceived level of sense of community in online courses (Rovai, 2002).

Instruments

Learning Experience Survey: This 10-item survey was self-developed by the researchers of the present study based on the standard online course evaluation surveys used by the distance education departments of two major American research universities. The survey includes five six-point Likert-scaled items on students' satisfaction level with online learning and instruction (reliability *Alpha* = .90), and five open-ended items on students' time spent on online courses.

The Classroom Community Scale (Rovai, 2002) is an instrument to assess students' sense of community and the extent of community development within a course. Rovai (2002) defines *sense of community* as consisting of two components: feelings of connectedness among community members and commonality of learning expectations and goals. The CCS contains 20 Likert-scaled items, ten items each for the subscales of connectedness and learning. Rovai (2002) has field-tested the CCS with university graduate students enrolled in e-learning courses, reported a high internal consistency of the total scale. Since its publication the CCS has been cited or applied in quite a few learning community studies (e.g. Anderson, 2004; Blignaut & Trollip, 2003; Brook & Oliver, 2003). The reliability for the CCS in this study was .93.

The Study Process Questionnaire (Biggs, Kember, & Leung, 2001) is a 20-item Likert-scaled survey used to determine participants' self-perceived learning stages or approaches in two dimensions – Deep Approach (DA) and Surface Approach (SA). Each dimension was measured by 10 items. The reliabilities for these two latent dimensions/factors were 0.82 and 0.86 respectively. In this study, students' scores in DA dimension and SA dimension were used as two continuous variables representing their self-perceived level of deep learning and surface learning respectively.

Online Learning Interaction Coding Scheme: In order to evaluate the objective evidence for adult students' cognitive and social engagement, the authors of this study conducted content analysis with archived online interaction transcripts. In agreement with Beers, Boshuizen, Kirschner, and Gijselaers (2007), the authors of this study held the belief that a new online collaborative learning research project, when focusing on a different theoretical framework or a different research purpose, will generally require new coding themes for analysis. Therefore, rather than using an existing content coding themes, we analyzed the online interaction transcripts using a self-developed analysis schemes - *Online Learning Interaction Model*.

This model was developed based on the theoretical framework of *deep* learning (Cercone, 2008; Fink, 2003; Moon, 1999) and a synthesis of the two representative content analysis schemes in the distance education literature: Henri's work (1992) that examined the quality of online postings based on cognitive information processing model, and the framework of Gunawardena, Lowe, and Anderson (1997) that examined evidence of knowledge building in online forums from a social constructivism paradigm. The current model holds the social constructivist view of learning but also keeps students' cognitive perspective in consideration.

In this model, the unit of analysis was "thematic unit" (Henri, 1992). Each unit was classified into one of the eight analytic categories under three dimensions, as outlined in Table 1. This coding framework highlights a knowledge construction process that ranges from the stage of *surface, individualistic learning* (K1) gradually (K2 as transition) to *deep, collaborative learning* (K3 and K4) where the learner actively synthesizes and integrates new ideas and then turns new knowledge into applications. It also addresses social interactions (S) and self-regulated or self-directed processes that comprise learning-oriented self-reflection (R2), teamwork coordination (R1), and technical issues management (R3).

Two raters coded the online interaction transcripts. After reaching 100 percent agreement on scoring two sample weeks' transcripts, both raters double-blindly scored the rest transcripts. The inter-rater reliability is .87. The two raters also discussed the differences in their codes and reached an agreement at 100%. The final revised codes were used for analyses.

Analysis

With quantified data on students' involvement with different categories of online learning interactions, as well as the results of the surveys, the researchers then conducted inferential statistics to predict causal-effect relationships between online discussion contexts and online students' perceptions and performance.

Table 1: Online Learning Interaction Model

Code	Category		Definition
S	Social Interaction		Having the indicators of greetings, comments without elaboration (e.g., "I agree with you"), personal life, and emotional expressions.
K1	Knowledge Construction	Sharing information	Simply adding facts, opinions, or questions without elaboration
K2		Egocentric elaboration	Elaborating one's own arguments/concepts/problem solutions
K3		Allocentric elaboration	Comparing and synthesizing peers' multiple perspectives
K4		Application	Planning future application of new knowledge or proposing in-field application strategies; developing new perspectives
R1	Regulation of Learning	Coordination	Teamwork planning and coordinating for collaborative projects
R2		Reflection	Self-evaluation and self-regulation on learning process
R3		Technical issues	Questioning and answering on technological problems or assignment clarification

Findings

Effects of Discussion Types on Learning Perceptions

An ANCOVA test was conducted to investigate the effect of discussion types (student-to-student, n=26; student-to-instructor, n=19) on students' satisfaction with the online course. The assumptions for ANCOVA were met. The test was significant, F (1,41) = 5.08, p < .05 [*effect size (partial* η2) = 0.11]. The mean satisfaction rating adjusted for age difference was different across the two online discussion types. The adjusted mean of the *student-led* discussion type (M = 27.18) was significantly higher than that of the *instructor-led* discussion type (M = 23.65).

Another ANCOVA test was conducted to investigate the effect of discussion types on students' scores in the classroom community scale, with the effect of age difference removed. The assumptions for ANCOVA were met. The test was almost significant, F (1,42) = 3.77, p = .06, indicating a potential difference between the two discussion types in promoting students' sense of community. Student-led interactions (M = 92.22) seemed to create higher sense of community score than instructor-led interactions (M = 80.17) did.

A MANCOVA test was conducted to investigate the effect of discussion types on students' scores of the *deep* approach subscale and scores of the *surface* approach subscale. The test was not significant. There was no enough evidence suggesting that by removing the effect of age, there was significant difference between two discussion types in reinforcing students' self-reported degree of deep or surface learning.

Effects of Discussion Types on Interaction Performance

An ANCOVA test was conducted to investigate the effect of discussion types (student-to-student, n=26; student-to-instructor, n=19) on the quantity of social interactions, by removing the effect of age difference. The assumptions for ANCOVA were met. The test was significant, F (1,41) = 5.14, p < .05 [*effect size (partial* η2) = 0.11]. The mean social interaction quantity adjusted for age difference was different across the two online discussion types. The adjusted mean of the *student-led* discussion type (M = 9.72) was significantly higher than that of the *instructor-led* discussion type (M = 2.10).

The ANCOVA test on the effect of online discussion type on the total amount of knowledge-constructive interactions was not significant. However, the MANCOVA test examining the effect of discussion type on the two higher-level, collaborative knowledge-constructive interactions (K3 and K4) was significant, F (2,40) = 6.54, p < .01, [*effect size* (*partial* η2)=0.25]. Examination of univariate results showed that significant discussion type differences occurred on both K3 interactions [F (1,41) = 6.48, p < .05] and K4 interactions [F (1,41) = 9.52, p < .01]. The adjusted mean for K3 interactions of the *student-led* discussion (M = 5.39) was significant higher than that of the *instructor-led* discussion (M = 1.45). Then, the adjusted mean for K4 interactions of the *student-led* discussion (M = .61) was still significant higher than that of the *instructor-led* discussion (M = .01). But in the MANCOVA test, the assumption on the variance homogeneity across the groups was rejected. Therefore, two Kruskal-Wallis tests were conducted to re-investigate the influence of online discussion types on K3 and K4 interactions. The tests were still significant: for K3, H=15.4, 1 d.f, P=0.000; for K4, H=8.58, 1 d.f, P=0.003.

An ANCOVA test was conducted to investigate the effect of online discussion type on the total amount of learning-regulation interactions (sum of R1, R2, and R3), with the effect of age removed. The test was not significant. However, the ANCOVA test examining the effect of discussion types on the amount of reflection-oriented learning-management interactions (R2) was significant, F (1,41) = 3.84, $p < .05$ [*effect size (partial* $\eta 2$)=0.09]. The adjusted mean of the *student-led* discussion type (M = 1.02) was significantly higher than that of the *instructor-led* discussion type (M = 0.01). But it should be noted that the effect size is small.

Effects of Grouping Design on Learning Perceptions

An ANCOVA test was conducted to investigate the effect of discussion grouping (group discussion, n=18; class-wide discussion, n=18; and the integrated of the two, n=9) on students' satisfaction with the online course, by removing the effect of age difference. The assumptions for ANCOVA were met. The test was significant, F (2,40) = 4.17, $p < .05$ [*effect size (partial* $\eta 2$)=0.17]. The adjusted mean of the *class* discussion (M = 23.06) was significantly lower than that of the *group* discussion (M = 27.79) and that of the *integrated* discussion (M = 26.83).

An ANCOVA test was conducted to investigate the effect of discussion grouping on students' sense of community, by removing the effect of age difference. The test was not significant. However, a pair-wise comparison between group discussion and class discussion was significant ($p < .05$), indicating a potential difference between the two participation units in promoting students' sense of community. Group discussion (M = 93.57) seemed to create higher sense of community score than class discussion (M = 79.50) did.

A MANCOVA was conducted to investigate the effect of discussion grouping on students' scores of the deep approach subscale and the scores of the surface approach subscale. The test was not significant. There was no enough evidence suggesting that by removing the effect of age, there was significant effect of the discussion grouping in reinforcing students' self-reported degree of deep or surface learning.

Effects of Grouping Design on Interaction Performance

An ANCOVA test was conducted to investigate the effect of discussion grouping (group discussion, n=18; class-wide discussion, n=18; and the integrated of the two, n=9) on the quantity of social interactions, by removing the effect of age difference. The assumptions for ANCOVA were met. The test was significant, F (2,40) = 10.16, p < .01 [*effect size (partial* $\eta 2$)=0.34]. The adjusted mean of the integrated discussion (M = 16.96) was significantly higher than that of the group discussion (M = 7.17) and that of the class-wide discussion (M = .51); then the adjusted mean of the group discussion is significantly higher than that of the class discussion

An ANCOVA test was conducted to examine the effect of discussion grouping on the total amount of knowledge-constructive interactions (sum of K1, K2, K3 and K4), by removing the effect of age difference. The test was not significant, indicating a lack of evidence for the effect of the discussion-participation units on the overall quantity of knowledge-constructive interactions. The further tests on the effect of discussion grouping on the individual types of knowledge-constructive interactions were not significant either.

An ANCOVA test was conducted to investigate the effect of discussion grouping on the total amount of learning-regulation interactions (sum of R1, R2, and R3), by removing the effect of age difference. The test was significant, F (2,40) = 6.22, $p < .01$, [*effect size* (*partial* $\eta 2$)=0.24]. Pairwise comparisons indicated that the adjusted mean of the *integrated* discussion (M = 14.01) was significantly higher than that of the *group* discussion (M = 6.30) and that of the *class-wide* discussion (M = 1.28). However, the assumption on the variance homogeneity across the groups in the ANCOVA test was rejected. Therefore, a Kruskal-Wallis test was conducted to re-investigate the influence of discussion grouping on the total amount of learning-regulation interactions. The test was still significant: H=6.55, 2 d.f, P=.04.

Then, an ANCOVA test was conducted to investigate the effect of discussion grouping on the amount of interactions for planning/coordination (R1), by removing the effect of age difference. The assumptions for ANCOVA were met. The test was significant, F (2,40) = 9.05, $p < .01$ [*effect size (partial* $\eta 2$)=0.31]. The adjusted mean of the *integrated* discussion (M = 10.77) was significantly higher than that of the *group* discussion (M = 4.36) and the *class-wide* discussion (M = 0.59). The adjusted mean of the *group* discussion then was significantly higher than that of the *class* discussion. However, the assumption on the variance homogeneity across the groups in the ANCOVA test was rejected. A Kruskal-Wallis test was conducted to re-investigate the influence of discussion-participation units on the overall quality of learning-management interactions. The test was still significant: H=14.02, 2 d.f, P=.001. The ANCOVA tests on the effect of discussion grouping on the amount of the other two learning management interactions (R2 and R3) were not significant.

Effects of CMC Environments on Learning Perceptions

Three analyses of covariance were conducted to investigate the impact of the CMC environment on students' perception of learning. The independent variable, the CMC environment, involved two levels: asynchronous only (n=22) and hybrid (integrating asynchronous and synchronous communication tools, n=23). The dependent variables include students' course satisfaction level, the score of sense of community scale, the score of the deep approach subscale and the score of the *surface* approach subscale in the learning process questionnaire. The age was used as the covariate. None of the analyses was significant. Therefore, there was no enough evidence suggesting that by removing the effect of age, there was significant difference between two CMC environments in reinforcing students' satisfaction level, sense of community within online courses, or self-reported degree of deep or surface learning approach.

Effects of CMC Environments on Interaction Performance

Three ANCOVA (with age as the covariate) was conducted to investigate the effect of the CMC environment on the amount of social interactions performed, on the total amount of knowledge-constructive interactions performed, and on the total amount of learning-regulation interactions performed. None of the three ANCOVA was significant.

However, a MANCOVA test indicated that by removing the effect of age difference, there was a significant difference between *asynchronous-only* courses and *hybrid* courses in the adjusted means of two knowledge-constructive interactions (K1 and K2), F (2,40) = 4.19, $p < .05$, [*effect size* (*partial* η2)=0.17]. Examination of univariate results showed that significant course model differences occurred on the amount of K1 interaction only, F (1,41) = 5.33, $p < .05$. The adjusted mean of the *asynchronous-only* courses (M = 27.43, n=22) was significant higher than that of *hybrid* courses (M = 10.92, n=23).

The MANCOVA test (with age as covariate) on the effects of communication technology application on the two higher-level knowledge-constructive interactions (K3 and K4) was not significant. Similarly, there was no significant effect of communication application on the interactions for teamwork planning/coordinating (R1), reflection (R2), or technical issues (R3).

Discussions

The study results indicated that student-to-student discussions, in comparison with student-to-instructor ones, predicted higher satisfaction, more social interactions, more high-level knowledge-constructive interactions, more reflection-oriented interactions, and potentially stronger sense of community. This pattern confirms the suggestion of prior research that student contributions in online discussions may increase when the discussions are not instructor led (Cifuentes, Murphy, Segur, & Kodali, 1997; Rovai, 2007) and that more peer interaction results in higher learning outcomes (Moller, Harvey, Downs, & Godshalk, 2000). As Dennen and Wieland (2008) reported, when students were involved in monologic posts that were oriented toward the instructor, there was less peer-interaction among learners, hence less social interaction or collaborative knowledge construction. In addition, it was observed that the instructors, as the single interactee for all students, seemed to be overwhelmed by the volume of the posts and were not able to provide responses to all messages, hence not creating a discussion environment that promotes deep learning through interactive learning dialogues.

Finally, it was found that group discussions, in comparison with class-wide discussions, predicted higher satisfaction level and stronger sense of community among adult students. This finding did not support the finding of Bullen (1998) that students appreciated the whole-class discussion because of the "many-to-many" communication options it offers. However, it addressed the qualitative notes of Dooley and Wickersham (2007) that the whole class discussion created the discussion threads that were overwhelming in number and made individuals become lost, be distracted, and lose equal opportunity to voice their opinions and thoughts and demonstrate their understanding to their peers and instructor. On the other hand, although Dooley and Wickersham (2007) expressed concern that lower level of critical reflection and deep learning would occur in the whole class discussion that in smaller, group discussions, their concern was not supported in this study. There was no enough evidence suggesting that adult students in class-wide discussions, in comparison with those in group discussions, demonstrated different levels of performance in knowledge-constructive interactions or reflective interactions.

Actually, the study results suggested that adult students in the online courses that integrated class-wide and group discussions perform most social interactions and learning-regulation interactions. An interpretation is that an integrated online discussion environment enables adult students to access multiple ideas and opinions in the class forum and at the same time provide them a group forum where they can remain focused and better manage the discussion threads.

The study did not indicate any added or compromised value by using synchronous communication tools in online courses for adult students. Prior research suggested that synchronous communication may improve social presence and social interactions but sacrifice the topic-related discussions (Im & Lee, 2004). Such a suggestion was not confirmed in the study since there was no significant difference between asynchronous communication environment and the integrated one in predicting emotional sense of community, learning satisfaction, or general online interaction performance. On the other hand, this finding supports the conclusion of Cleveland-Innes and Ally (2004) that there was no significant difference between synchronous and asynchronous communication tools in reinforcing learning outcomes for adult continuing education.

However, there is a potential trend that interactions for the first level knowledge-constructive interaction - information sharing in discussion forums – may be reduced in an integrated communication environment. A possible reason may be that part of interactions for information-sharing was released from the discussion forums to the synchronous communication environments (text chat-room or computer conferencing) that enable timely and verbal exchange of fact and information. A potential consequence of such a pattern is that adult students may concentrate their efforts in deep learning interactions (i.e., K3, K4, or R2) in online discussion forums. However, this proposition was not supported by the study since adult students in the integrated communication environment did not demonstrate better performance with deep learning interactions. It is possible that the "floor effect" – generally very low participation in K3, K4, or R2 discussion types – has made it difficult to detect the difference between the two communication environments. It is recommended to conduct further research with a bigger participant pool to investigate the difference between the two communication environments.

Significance of the Research

The study is an initial attempt to explore learning environment pedagogies that positively impact adult students in online contexts. It is an important complement to the existing literature on e-learning instructional design, adult education, and cognitive aging. Practically, the findings inform educationalists how to design online discussions for adult students as they create successful distance education programs.

Endnotes

(1) In an instructor-led discussion forum, the instructor typically lead every discussion thread and the discussion posts under each thread comprise mostly instructor-student discourses rather than student-to-student peer discussions.

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When Is Collaborating With Friends A Good Idea? Insights From Design Education

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Abstract: Prior research is split on the relationship between prior friendship and performance. Based on our review of the literature, we highlight areas where further research is needed to achieve greater practical applicability of the results. We then present our study measures and preliminary analysis of data collected from a design studio university course. Our quantitative and qualitative probes suggest a link between teammates' prior friendship and lower performance outcomes. We also identify four group processes that may mediate the relationship between friendship and performance.

Introduction

This paper presents a study of how prior friendship in student groups influences learning and performance in computer-supported collaboration. We review earlier studies on friendship, highlight the dimensions in which our work differs, describe the context, data collection strategies for assessing the impact of students' friendships, and present preliminary statistical analyses. The results show a significant, large negative correlation between prior friendship and performance. We bring together quantitative and qualitative methodologies to understand the ways in which the *relationship between project quality and pre-existing friendship among teammates plays out in design project collaborations*. We conclude by describing the next steps to evaluate the causal direction of this relationship, and suggest that collaboration in teams where some teammates are friends and others are not (i.e., mixed-friendship groups), may be the worst possible combination of friends and non-friends in project teams.

Our data is drawn from a design and implementation project, completed by thirty-nine university students working together in teams as a part of their coursework for six weeks. The need for understanding the relationship between collaborative processes, practices, behaviors, and successful outcomes is particularly salient in this domain because design problems lack true-or-false solutions. Instead, they feature better-or-worse comparisons among potential, interdependent solutions (Cross, 1984). We are especially interested in the effect of *prior* friendship relationships between teammates rather than on the friendships that develop through the collaboration, although we evaluate both. Prior friendship can be ascertained before the project begins, and guide group composition. Other characteristics and factors of groups that impact performance – such as the development of friendship among teammates — occur through the interactions among group members, are susceptible to context and circumstances, and are therefore harder to predict.

Prior Research On Collaboration Among Friends

Researchers remain split about the relationship between group members' friendship and outcomes, and the prior published work on friendship among students has left important areas in need of inquiry. First, consider the research that highlights the benefits of friendship in collaborative task performance. Newcomb and Bagwell (1995) found friendship collaborations to have more intense social activity, more frequent conflict resolution, more effective task performance, and to be marked by reciprocal and intimates properties of affiliation, greater equality, mutual liking, closeness, and loyalty. Theorists have also suggested that the psychological context of friends collaborating may be associated with productivity and learning gains (Azmitia, 1996; Shah & Jehn, 1993), as well as social and emotional growth (Newcomb & Bagwell, 1995). The ease of establishing a shared problem-solving space in groups of friends has also been linked to successful outcomes (Barron, 2003; Brown, Collins, & Duguid, 1989), arguably from the group members' familiarity with the prior knowledge, communicative strategies, and thinking styles of their partners.

Others believe that working with friends yields lower-quality outcomes because friends have more off-task, disruptive behavior, stronger pressures to agree, and reluctance to be critical of each others' ideas (Dutson, Todd, Magleby, & Sorensen, 1997; Zajac & Hartup, 1997). Prior work found that groups of friends both disagree more frequently (Shah and Jehn, 1993) and are more concerned with resolving disagreements (Newcomb & Bagwell, 1995) than those composed of non-friends. That is, people find it easier to disagree with friends on topics of low importance (such as whether the referee was unfair) and discuss the topic until agreement is reached. Yet it is harder to critique friends' important decisions (*e.g.*, "I don't think you should buy that house/date this person") even when the outcome would be better had these concerns been expressed. Even when debate is vital for a successful outcome, dense social network ties among members can "bind individual team members into mutual consensus and lack of disagreement" (Balkundi & Harrison, 2006), leading to poor performance while simultaneously creating perceptions of high affiliation and agreement among teammates (Janis, 1982; Strough, Swenson, & Cheng, 2001).

Prior research is limited in key respects if we wish to understand the relationships between the friendship makeup of groups and their work products over the significant periods of time commonly associated with authentic teamwork. Research has not reflected the heterogeneity of friendships common to educational environments, where a combination of friends, acquaintances, and others – whether strangers or disliked colleagues – work together. Instead, the groups previously studied are homogeneous with respect to friendship, comprised of all friends or all non-friends, with reciprocal assessments of the relationship. Most prior work compared "friend" and "non-friend" dyads by pairing participants with either pre-identified friends or with other participants (*e.g.,* Miell & MacDonald, 2000). On this binary view, non-friend dyads include both pairs that do not know each other and pairs that do not like each other. By aggregating these two distinct cases, it has been suggested that the "friend" condition fares more favorably than if it were compared simply against pairs who did not know each other (Strough, Berg, & Meegan, 2001). An additional factor to consider is that pairs may not rate each other symmetrically. This heterogeneity becomes especially important when studying groups larger than dyads.

As Strough, Swenson, and Cheng (2001) point out, few studies address whether the *products* friends create together are superior to those of non-friends, or examine friendship and collaboration over multiple sessions. The study presented in this paper is longer in duration (six weeks) and comprises more meetings (3-4 times/week) than prior work in this area. This is important because the effects of social ties between teammates have been shown to diminish as team tenure increases (Balkundi & Harrison, 2006). Therefore, it may be that the previously reported positive effects of friendship upon team performance are limited to initial contact.

Most collaboration research studies investigate same-gender dyadic interactions in a controlled environment during one or a small number of sessions. Few studies consider performance achievements in mixed gender groups, or for teams of 3 and 4 students (Shah & Jehn, 1993; Zajac & Hartup, 1997). And one review highlights how investigations of contrived laboratory tasks (such as Azmitia & Montgomery, 1993; Shah & Jehn, 1993) outnumber those of classroom contexts (*e.g.*, Strough, *et al.*, 2001b). One important way in which classroom collaborations differ significantly from laboratory studies is that the effects of the group's work impact all the teammates' performance beyond the timeframe of the study (Azmitia, 1996) – which may alter the observed importance placed on preserving the social relationship over outcome during decision making.

Method

The context for our research is design education, specifically a design studio course at Stanford University. We studied the course's final project, which accounts for a quarter of the students' course grade, and because of its reliance on computer-supported collaborative project work. The final project emphasizes iterative design and testing of a functioning interactive system. These student projects included an automatic lighting system for homes, an interactive teddy bear for hospitalized children, and a video conferencing system for mobile phones. It has been suggested that differences between friends and nonfriends' collaboration are most apparent on challenging tasks, such as these (Azmitia & Montgomery, 1993). Achieving success at these projects requires both individual and group work. Students form groups and select topics themselves. As we did not seek to alter or influence students' preferences in group formation, the groups we studied were heterogeneous with respect to friendship and were often mixed-gender. Rather than focus on dyads solving a laboratory task, this study examined 3- to 4-person groups as they formulated, conducted, and completed a complex, creative, open-ended project.

All 41 students enrolled in the design studio course in 2007 were invited to participate in the study; of these, 39 (13 female, 26 male) agreed. Participating students were provided with the study's consent form and a pre-experience questionnaire. At the last class meeting, after the project presentations, students were asked to fill in a post-experience questionnaire without knowing their course grades or the evaluation of their projects. Using relevant items developed in previous research (Bailenson & Yee, 2006; Hinds & Mortensen, 2005; Mercier & Barron, 2003), the questionnaires measured attitudinal, self-reported behaviors, and experiences within the groups (Maldonado, Lee, Klemmer, & Pea, 2007).

Participants were predominantly engineering students, with the majority pursuing degrees in Computer Science and related disciplines; 44% were undergraduate students (juniors and seniors) and 56% were enrolled in graduate programs. Participants volunteered their time at filling out the survey instruments; no remuneration was offered. The data were not visible to any course staff until after course completion, when solely aggregate and anonymized data were presented.

We asked students to rate their relationships to each of their teammates at the end of the class, as friendship nominations elicited before group formation may be influenced by perceived competency and achievements of their peers (Strough *et al.,* 2001a). Students choose between the categories: "friend," "acquaintance," and "non-friend". This last option of "non-friend" represents the situation when students did not previously know each other. (As we did not expect students to choose to work with people that they did not get along with, we did not include a friendship category for teammates actively disliked prior to the project). We calculated a *group friendship score* for each team by averaging teammates' individual friendship ratings. For example, each person on a four-person team rated their three partners, so the group friendship score represents the average of these twelve ratings. This approach of using averaging to create one measurement per group follows Balkundi & Harrison (2006).

Table 1: Correlation and Descriptive Statistics for Group Friendship and Project Performance.

Variable	Group friendship	Project Performance
Group friendship		-0.61**
Mean	0.437	30.98
SD	0.376	2.06
Min	0.00	26.4
Max	1.20	33.5

* $p < 0.05$, ** $p < 0.01$

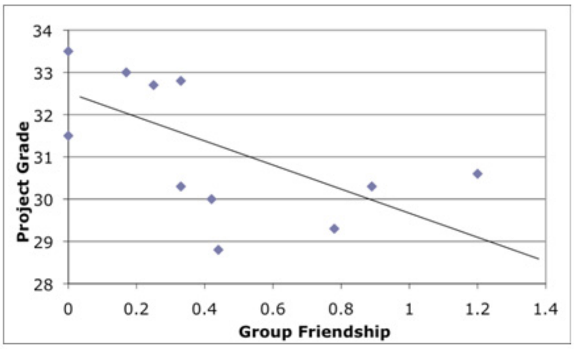

Figure 1: Scatterplot showing negative correlation between Group Friendship scores (X-axis) and Project Performance (Y-axis)

Team project performance was measured by project grade, calculated from assessments from the course staff (two instructors and two teaching assistants) and a panel of independent judges. After grades were distributed and the course had ended, students were invited to volunteer for interviews to discuss their technology usage and group dynamics in the course.

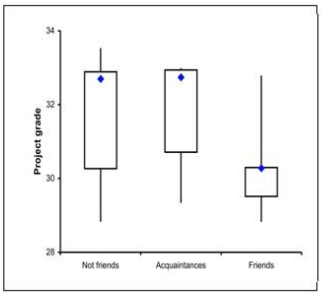

Figure 2. Project Performance of individuals who were friends with at least one teammate was lower than that of individuals who had no friends on the team.

Results

The unit of analysis for all results is the group. There was a large and significant negative correlation between the team's aggregate pre-existing friendship rating and their project grades (Pearson $r = -0.61$, $p < 0.01$; see Table 1 and Figure 1). Ten individuals—in five matching pairs—reported working with pre-existing friends; each pair was in a different group. Figure 2 plots, for each student, project grade against the level of friendship with their closest teammate. It shows that students who had a friend on their team performed worse than those that did not. None of the items in the questionnaire regarding self-evaluation of positive team dynamics (whether the group "had fun together," "got along well," "liked your teammates") was significantly correlated with the prior friendship of group members.

Discussion

Qualitative data drawn from the interviews conducted after the course supports the negative correlation between prior friendship and group performance. When asked how working with friends may help or hinder the groups during the interviews, one student remarked on the adage "do not mix business and pleasure: don't work with family or friends" for a good outcome. Three other students suggested that they preferred working with friends and explained their reasons, such as "he knows when my parents are in town, or that it's my girlfriend's birthday, and understands that's why I am late to meetings, or forgot to email my part." The students' statements suggest that teammates may partner with friends because of the slack it allows them. Conversely, when working with strangers students may feel the need to establish a reputation that they take for granted when working with friends. In either case, the students' comments imply that their contributions to the team are of lower quality when collaborating with friends.

We hypothesize friendship affects group performance in three places: team formation, group meetings, and project execution. In the former situation students may choose to partner with friends, rather than with the most talented students. Students may partner with friends because they are *loss averse* (Kahneman & Tversky, 1979): friends represent a known quantity, preferable to potentially nightmarish group mates. During meetings the pressure to agree (Newcomb & Bagwell, 1995), reluctancy to be critical of friends' work (Dutson, *et al.*, 1997), and supportive emotional environment (Azmitia, 1996; Hartup, 1996), may guide teams of friends towards lower quality or less well-developed project ideas. When comparing the dynamics of groups of friends versus those composed of non-friends, friends tend to have a positive orientation towards each other's ideas, and are reluctant to criticize each other, especially in front of others (Dutson, *et al.*, 1997).

Lastly, asymmetrical friendship levels within a group may impede the creation of a coherent, unified group identity. Teams with only *some* prior friends may be particularly prone to incur the above-mentioned quality costs of working with friends without realizing the quality gains, leading to the breakdown we see in Figure 2. All the groups we studied contained varying friendship strengths; no group was composed exclusively of friends. This is generally representative of real-world groups. However, it is possible that all-friends groups perform differently. This remains a topic for future study.

Conclusion and Next Steps

Prior research has been split on when the relationship between friendship and group performance is a positive or negative one. Our study analyzed the products and prior friendships of mixed-gender, heterogeneous friendship groups of three and four students solving complex, open-ended problems over a six week period. By studying classroom collaborations in the classroom rather than in the laboratory, we sought to provide advice of greater application relevance to educators and collaborative software designers. The contribution to the CSCL literature of this paper is that in these "real-world" conditions, we found a strong negative correlation between prior friendship and project performance, raising concerns about friendship-matched grouping. These findings provide empirical support for theoretical work (e.g., Azmitia, 1996) that posits that friendship makes a difference in the psychological context of collaboration. Several important questions remain. For example, how does the subjective satisfaction of friend groups compare to non-friend groups? Additionally, it would be valuable to compare friendship and performance in contexts beyond design education.

Prior research has often conflated group cohesiveness, skill complementarity, and friendship when linking to performance outcomes (Shah & Jehn, 1993). To determine the conditions under which it is advantageous or not to work with friends, we will be measuring and analyzing these three constructs separately. Separating them might explain some of the apparent differences in prior results.

An understanding of how group dynamics impact performance can suggest specific areas where the groups' experiences might be supported through novel designs of collaborative technologies and pedagogical practices. For instance, one could try to mitigate social pressures to agree by introducing secret–ballot voting, using anonymous chat for decision-making meetings, and/or formalizing a practice of critiquing group deliverables.

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Sustaining Collaborative Knowledge Construction in Graduate-Level Education: Examining Design Issues

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Abstract: This paper presents a design-based study of a graduate level course that uses CSCL methods to establish a unique pedagogical form of knowledge community. This interdisciplinary seminar is divided into a set of knowledge media themes, with a different group of students leading each theme. With each new offering of the course, students inherit a course wiki that aggregates the content and pedagogical knowledge from prior offerings. For each theme, the student leaders work closely with the instructor to design pedagogical approaches that engage the class in specific knowledge practices that are pertinent to the theme. This study considers the theme of "immersive environments", and analyzes instructor and student actions through three iterations of the course in terms of pedagogical designs and use of technologies.

Introduction and Purpose of the Study

ICT-supported higher education presumably accommodates active learning, facilitates extended collaborations beyond face-to-face class meetings and provides easy-access repository of resources (Chan & VanAalst, 2004; Bonk & Graham, 2006). Yet the controversial evidence about the quality of ICT integration in higher education (e.g. Vaughan, 2007) demands research-informed pedagogical approaches that truly foster social-constructivist perspectives of learning (Fischer, Rohde & Wulf, 2007; Levin-Peled, Kali & Dori, 2007). This study investigates the design processes of an ICT-integrated course in three consecutive offerings and aims to provide an understanding of the interplay among curricular decision-makings, designed learning activities, selected ICT tools and the learning outcomes as the students and the instructor negotiate their expectations from the course.

In this interdisciplinary graduate seminar each week one student-group selects a theme related to educational affordance of digital media (e.g., podcasts), plans before-class activities and moderates face-to-face class meeting. The instructor and the students together choose ICT tools that suit their CSCL needs and that facilitate a progressive record of the course history. The instructor aspires that students from all offerings form a knowledge community, adopting the ideas that characterize course themes as they are addressed in turn.

The following questions guide the study: (1) How do the instructor and his students negotiate the design and implementation of CSCL activities to achieve their learning expectations form the course? (2) How does the work of students in previous iterations affect current students' design to discuss similar themes? (3) How does the technological infrastructure of the course affect the students' learning experience?

Conceptual Framework

Theoretical perspectives of learning and pedagogical practices that overcome "inert knowledge" and "passive learning" are advocated by educational researchers, but difficult to implement within k-12 or higher education courses (Brown & Campione, 1996; Bereiter & Scardamalia, 2003). Complex problems of the "knowledge-society" that require graduates to apply their knowledge to new situations further necessitates these approaches. Many researchers advocate the notion of "Knowledge Community" and "Community of Learners" to support learning (Brown & Campione, 1996; Bereiter & Scardamalia, 2003; Scardamalia, 2002).

A synthesis of the underlying principles of collaborative knowledge construction as declared by these theoretical perspectives yields the following characteristics of an environment that supports deep learning: 1- A deliberate metacognitive layer increases learners' ownership in setting goals, leading discussions, and selecting learning resources. Application of metacognitive skills transcends individuals to the wider community, helping students take responsibility for monitoring and responding to their peers. 2- Collective expertise is distributed among students, instructors, and other experts; every member is knowledgeable in some aspect of the curriculum and contribution from all members is required to improve the current state of knowledge. Instructors have a critical role in a knowledge community and should balance their authoritative status not to suppress students' cognitive responsibility. 3- Supporting a community of discourse is another requirement to fostering learning communities in classrooms. Mastering discourse skills requires constant modeling and practice; e.g., providing opportunities for students to communicate with experts and with their peers. 4- Seeding generative ideas: A community of discourse allows students to propose ideas and discuss them with their peers. Students should identify generative ideas that can be later adopted and improved by other members of the community.

Supporting peer collaboration is central to pedagogical designs to develop knowledge community-like classrooms. CSCL technologies also support a knowledge community perspective in education by extending peer discussion and easing access to shared artifacts and resources. Despite theoretical promises, ICT-supported higher education courses tend to focus on knowledge transmission, sustain fixed curriculum, include pre-determined learning activities, emphasize individual achievement, use ineffective CSCL tools and employ rigid assessment procedures (Kirschner, Martens & Strijobs, 2004; Selwyn, 2007; Vaughan, 2007).

Study Design and Procedure

This study is best framed as design-based research (Collins, Joseph, & Bielaczyc, 2004), which brings research and practice together and allows for recursive examination of the interactions among multiple design elements. Results obtained and design implications derived from previous iterations inform future research iterations.

This study was conducted over three successive offerings of the "Knowledge Media and Learning" course and is focused on one of the course themes: "The immersive environments." This theme was selected for analysis because it was addressed in all three iterations of the course. Table 1 shows design iterations, participants and data sources. All names are pseudonyms. Students were interviewed after the course was over.

Table 1: Timeline, data sources and participants in each design iteration.

Design Iterations	Participants	Data Sources
1: Jan-Apr 2006	-One PhD student (Judy) -The instructor	-Classroom observation (from 3 iterations) -Interview with Judy, Group2 and Group3 -Course wiki (from 3 iterations) -Instructor's communications with Group2 and Group3 -Focus group with students from iteration1 and 2
2: Sep-Dec 2006	-One PhD & one Masters student (Group2) -The instructor	
3: Sep-Dec 2007	-Two Masters student (Group3) -The instructor	

Analysis

Following an inductive method and informed by the aforementioned characteristic of knowledge communities, data was reviewed after each iteration and emerging themes were identified (Marshall & Rossman, 2006). After the initial analysis, an Activity System framework (Engeström, 1993) (Figure1) was used to investigate the relationships between these components of the course: students, instructor, content and utilized ICTs.

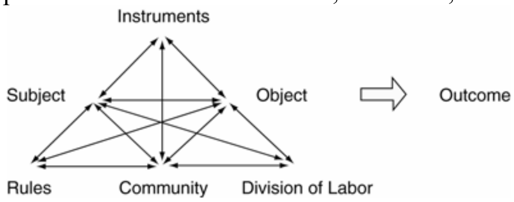

Figure 1. Activity system framework

Activity Theory is a suitable framework for the design and evaluation of ICT applications in education (Russel, 2002) and allows researchers to investigate how newly introduced ICT tools impacts the objects of the individuals and the community, the kind of contradictions that emerge, and the effect of new tools on learning experiences. Tensions between the elements of an activity system are driving forces for innovation and improvement. In this study the activity systems of the instructor and the students who presented the "immersive environments" theme were analyzed. Of interest were actions that the instructor and the students took to respond to the collective object of fostering a sustainable ICT-supported knowledge community.

Findings and Discussion

Design Iteration 1 (Spring 2006): Evolution of a New Course

The course was originally designed as a standard seminar and the instructor had planned to initiate deep, high-level discussions about research related issues pertaining to: "Technology, curriculum and instruction". His design proved obsolete once the class actually met with only two of the four students interested in discussing such topics. Therefore, the structure of the course had to change to be responsive to the new conditions. Once the instructor's original object was no longer feasible, he changed the object of the activity to meta-designing a course to be offered the next term in an interdisciplinary institute within the same university. This format changed the division of labor, requiring students to become co-designers and demanding a higher level of responsibility with regards to the quality of their work. Under the instructor's guidance, the students were expected to propose generative ideas and identify useful resources for the topics selected for the in-design course. According to the instructor, the class gradually moved towards becoming a learning community.

Designing for Immersive Environments

Judy's activity was situated in a tension-intensive context. Yet by the time she was to lead the "immersive environments" topic, she had a good understanding of course expectations in terms of the quality of the materials and the nature of collaborative learning activities. The instructor maintained close collaboration with the student responsible for each topic and Judy was pleased with the guidance that she received: "[the instructor] was the official course instructor but he was more of a discussion leader. Sometimes he explained things and gave very good analogies of different research designs like fundamentals of it" (Interview data).

Judy wanted to understand "immersive environments" and to help her peers understand them as well. The other three students were given substantial responsibility and were asked to select one of the subtopics, as specified by Judy, and prepare a brief presentation on that. Judy 's role changed into moderating a session where each of the students possessed a certain degree of knowledge and expertise about the topic.

Earlier in the course, the students and the instructor had decided to develop a wiki space to represent their learning experience "… a space where we could capture our discussion which we could all access and edit" (Interview data). After the course ended, Judy and the instructor re-organized the wiki so that future students could better identify generative ideas and use the existing knowledge as a springboard. Consequently, Judy's perspective of the course material became the dominant in the course wiki. Although it is possible to check the original wiki pages through the history, the collaborative nature of the course became less evident in the wiki.

Design Guidelines for the Second Iteration

One outcome of this iteration was a wiki that showed the topics selected by students, pedagogical approaches, and the knowledge base developed during the first iteration. Collaborative development of a technology-supported record of the course became one guideline for the second design iteration of the course. The instructor also deiced to maintain a flexible course outline to accommodate students' interests and expertise.

Design Iteration 2 (Fall 2006): Promoting Student Agency

In iteration 2, the instructor was interested to know how the pedagogical beliefs and expectations for peer collaboration from iteration 1, as represented in the wiki pages, was identified and pursued by new students. During iteration 1 the instructor gradually developed a vision for the course, he still found it challenging to clearly articulate the objectives of the course. The new class spent two weeks brainstorming their learning goals. Although the wiki from the first iteration was introduced early on, the themes did not appeal to the students as they spiraled out of the theoretical material and suggested more recent topics such as social networking. The object of the course remained evolving for the rest of the term, causing confusion for some of students.

The course had a rocky start because the students were new to the idea of designing a course for themselves. However, the instructor noticed that as the course proceeded, the mind-set of the class changed and the students gradually took more responsibility toward identifying their learning goals and planning to enact them. The students in iteration 2 came from faculties across campus including: Education, Information Studies and Mechanical and Industrial Engineering. Interdisciplinary groups could be formed to lead the class discussions. Students made a growing list of specific and more general technological tools. The first topic to be presented was the immersive environment. With 14 students in the class dedicating sub-topics of the theme to every student was impossible. The participation expectation from students changed to: Becoming familiar with the theme of the paper by reading the assigned papers and actively engaging in discussions.

Designing for Immersive Environments

Before the presentation, Group2 divided the class into small groups, assigned each group different papers to read to become "expert" in one aspect of immersive environments. During the class, each groups answered a series of questions posted to a wiki page and used them in the whole class discussion. Group2 worked closely with the instructor but, as one of them mentioned, the instructor refrained from directing their activities and gave them the opportunity to discover their way of framing the presentation.

Group2 explained their intentions as to explore the "variety of ways that these immersive environments could enhance or facilitate [collaborative learning] because the immersive environment have the ability to stretch the boundary of the physical space or reality. So we wanted to understand the possibilities of using the immersive environments that can enhance real world learning" (Interview data). Their search for feasible immersive environments yielded little result, since the functioning immersive environments demanded top of the line computer systems. With the advice of the instructor, they shifted the focus from hands-on experience with immersive environments to thinking collectively about the implications of such environments for learning.

Outcome of Judy's activity, the immersive environments wiki pages, was a starting point for Group2 who critically assessed these wiki pages to separate outdated and usable concepts. The immersive technologies introduced before were mostly non-functional making the object of iteration 1, developing a set of improvable object, compromised. Yet Group2 recognized that the theoretical concepts were still useful. In their wiki pages, they built on the knowledge represented in iteration 1 and added their own ideas with the hope that future students would critically appraise those ideas and further improve them.

In this iteration, the wiki space developed in iteration 1 was introduced to the students as a possible virtual home for the course. Still, the instructor and the students realized that the class needed a communication medium to maintain contact between the weekly meetings. Considering the abundance of collaboration and communication tools available in Sakai, it was selected to replace the existing wiki. Later, Sakai was abandoned due to continuous technical problems and another wiki platform was chosen. Group2 put a summary of their work in the new wiki and provided a link to the old wiki. Changing technologies caused more work for Group 2 showing one of the challenges of maintaining a sustainable knowledge community.

Design Guidelines for the Third Iteration

Self-evaluation gradually became a part of theme presentation for groups to increase students' agency toward their learning. For students in iteration2, self-evaluation happened in hindsight as a unified template for representing the design and its outcome, as themes was not developed until toward the end of the term. A reflective stance toward learning could encourage the students to advance community knowledge base.

Design Iteration 3 (Fall 2007): Identifying Improvable Ideas

Students in the third iteration had a very different demographic comparing to the second offering, with one third of the class coming from a library sciences branch of information studies. Similar to Iteration 2, the instructor did not solidify the structure of the course and expected the students to overcome their uneasiness with an unusual course. However, he found it difficult not to describe the structure of the learning community of iteration 2: "As in the previous iteration, I found myself doing some quick dance steps in the early weeks to try to convey the key ideas, even as I was still in the midst of figuring those ideas out form myself. But then in the next breath, I would tell them how it would be done- with the themes, and the knowledge activities, etc. There is a fine balance with any student group, because they need some structure and definition." (Interview data) The class demanded more direction and, unlike students in iteration 2, readily adopted existing discussion themes. The structure resulting from iteration 2 was taken for granted although later in the course students slightly let their guards down and experimented with defining the problems they wanted to solve.

Designing for Immersive Environments

The design and implementation of the immersive environment took a drastic turn. The ideas presented by Group3 hardly built on the existing knowledge and with little communication between the instructor and Group3. This group did not meet with the instructor until after they had finalized the presentation plan. The two students in this group had extensive previous experience with high fidelity video games and simulations and assumed little point to share their design with the instructor in order to get his feedback.

When asked how the instructor was involved in their design on of the group member said: "What the instructor did best was to make provocative statements and make us think differently about what we were discussing and that was an effective way to go about it, considering we were discussing new paradigms in technology and education" (Interview data). The instructor, on the other hand, wished to have met with them earlier because Group3 changed the focus of discussion from thinking in terms of designing immersive environments for learning, to "get people to think about what immersive environments are beyond any sort of stereotypical understandings they might have of them" (Interview data). During the class the students worked with different gaming environments in rotational groups. Yet, their activities lacked a collaborative quality.

Group2 hoped that future students critically evaluate their design and further improve it. Instead, Group3 completely changed the nature of the theme. The two students in this group reviewed the last iteration but did not refer to it in during the discussion leading. As a result, is unlikely that other students in the third iteration would have ever visited the work that had been done in the previous iteration. Because the focus of the theme changed without making many connections to what previously had been done, it is hard to decide whether Group2's design for the immersive environments had a capacity to be further developed.

Design Guidelines for the Fourth Iteration

After iteration 3, students from all three iterations were consulted about the changes they would recommend. A recurring request was to decrease the number of the themes to allow for deeper discussion. Also, to make knowledge base more visible the instructor decided to dedicate the first two sessions of iteration 4 to reviewing the course wiki. A comparison of the theme designs and class discussions from the past three iterations revealed a relationship between dominant characteristics of students in a given iteration and cohesiveness of the sought-after persistent knowledge community.

Conclusion

"Knowledge Media and Learning " promotes deep thinking about the implications of new technologies for formal and informal learning contexts. Students are expected to develop a critical understanding of the affordances of various genres of technology while becoming able to flexibly apply their knowledge to new situations (Bereiter & Scardamalia, 2003). Informed by the issues that surfaced in three iterations of this study, it is possible to suggest interim guidelines for similar situations where students co-design their learning.

Despite being at a gradate level of education, not all students may appreciate the diversity of expertise in a learning environment. In the next iterations, it would be possible to explicitly model (Brown & Collins, 1996) the advantages of integrating multiple expertise in designing learning experiences. Moreover, the instructor should make his role as the expert in the learning sciences more explicit so that the student s feel the need to consult with him to ultimately avoid misconceptions about learning and also exaggeration of the strength or weaknesses of technological tools to be used in learning.

As the course gained more structure, the students' responsibility toward identifying their learning needs and designing learning environments to meet those needs may decrease. One example is the course wiki, which in the third iteration became a tool for sharing students' works rather than helping them to frame the learning process. Yet the class could go into a viscous circle if the students in the third iteration were expected to design another virtual presence for the course, similar to what the students in the second iteration undertook.

Studying students' and the instructor's joint effort to co-design a graduate seminar, allowed us to gain an understanding of how the instructor and the students together as a members of a learning community can engage in generative discussions. In the next iteration, the instructor intends to emphasize the conceptual aspect of each theme to balance students' tendency to adhere to applied aspects. Conceptual emphasis can give community members a sense of identity that goes beyond knowledge of ever-changing technological tools.

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Collaboration and the Net generation: The changing characteristics of first year university students

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Abstract: This paper reports on the first phase of research that investigates the Net generation entering university. The paper focuses on claims about the Net generation's relationship to collaboration and cooperation and the ways that this relationship is associated with technological rather than social processes. Based on a survey of first year students in five universities across a range of subjects and disciplinary areas, the paper concludes that we should be cautious about the claims that have been made about Net generation learners. It suggests that broad brush approaches to generational changes obscure the subtle but important differences between students. It also suggests that claims that there has been a step change in attitudes takes attention away from the kinds of choices that might be necessary in relation to variations that are indeed taking place amongst new cohorts of students.

The Net Generation

The term Net generation originates in the work of Tapscott (1998 and 2008). His arguments are about an entire generation.

> Today's youth are different from any generation before them. They are exposed to digital technology in virtually all facets of their day-to-day existence, and it is not difficult to see that this is having a profound impact on their personalities, including their attitudes and approach to learning. Tapscott (1998 a)

Tapscott uses his arguments about the Net generation to argue that technological changes lead to 'inevitable' consequences for teaching and learning. "But as we make this inevitable transition we may best turn to the generation raised on and immersed in new technologies." (Tapscott 1999 p11). The change favored by Tapscott is a move from teacher-centered to learner-centered approaches and he claims that the ultimate interactive learning environment is the internet itself.

A second common source for arguments about the Net generation comes from articles written by Prensky and the idea of Digital Natives (Prensky 2001 and 2001a). Prensky argues that digital natives are part of a generation that have:

> .. not just changed *incrementally* from those of the past, nor simply changed their slang, clothes, body adornments, or styles, as has happened between generations previously. A really big *discontinuity* has taken place. One might even call it a "singularity" – an event which changes things so fundamentally that there is absolutely no going back. (Prensky 2001 p 1)

Presnky's comments were made directly in relation to students but they were about the entire generation in schools and colleges and not limited to those pursuing higher education. The discontinuity described by Prensky focused on *thinking* and *processing* differently. Prensky even makes the claim that the brains of the new generation are different (Prensky 2001a). Prensky's claim was that the biggest problem in education was a disconnect between 'digital native' students and 'digital immigrant' staff who retained the 'accent' of a different era even when they were fully socialized into a digital environment. Prensky argues that if you are not part of the new generation you will always be marked by your earlier experience. In this sense being a digital native or a digital immigrant is not a learned skill it is a fixed product of early development.

Despite having slightly different emphases both Prensky and Tapscott rely heavily on technological determinist arguments. Tapscott's argument that changes to pedagogy are 'inevitable' is a classic example of this flawed approach. A further source of arguments about this new generation of students comes from Diana Oblinger of EduCause who has called the generation born after 1982 the Millenials and claims that this group:

- gravitate towards group activity
- identify with their parent's values and feel close to their parents
- spend more time doing homework and housework and less time watching TV
- believe "it is cool to be smart"
- are fascinated by new technologies
- are racially and ethnically diverse and
- often (at least on in five) have one immigrant parent.

This description of the Millenials unlike the work of Prensky and Tapscott is empirically based and is supported by large scale annual surveys of students in the USA (see for example Salaway et al. 2008). Oblinger's argument is strongly related to Prensky's ideas and Oblinger claims to have found a trend towards an internet age mindset. She also agrees with Prensky that there is a disconnect between the new Millenial students and the institutions that they are enrolled in. However Oblinger and Oblinger (2005) do not agree that the determinant is simply age: "Although these trends are described in generational terms, age may be less important than exposure to technology." (2.9). This difference in understanding allows for older students to have different approaches based on their exposure to new technologies.

Although the arguments of these three authors are actually somewhat different they are used widely and largely interchangeably. There has been relatively little discussion of these themes in recent CSCL conferences (Shih and Swan 2005) or in the international journal of CSCL, but in the wider literature there has been a more developed discussion of the issues that the Net generation raises, and this discussion has included discussion in relation to CSCL (e.g. Nilsen and Instefjord 2000)..

Net generation and collaboration

The Net generation argument has consistently associated the rising generation with new forms of sociality and a desire to work in teams or group. Most recently Tapscott's new book includes this comment: "In education they [the Net generation] are forcing a change in the model of pedagogy, from a teacher-focused approach based on instruction to a student-focused model based on collaboration." (2008 p 11). There are from our point of view two interesting aspects of this argument. Firstly the Net generation are 'forcing' this change, a twist on the technological determinism noted earlier, to which Tapscott has now added a generational determinism as if the Net generation controlled the educational institutions in which they are largely subjects. Secondly the association of the new pedagogy and a student-focus with collaboration, as if this was the sole and specific way that student-focused education could be obtained.

Oblinger and Oblinger express an equally generalized notion of collaboration arguing in relation to teams that:

> The Net Gen often prefers to learn and work in teams. A peer-to-peer approach is common, as well, where students help each other. In fact, Net Geners find peers more credible than teachers when it comes to determining what is worth paying attention to. (2005 2.7)

The argument that there is a Net generation has an educational component which suggests that the new generation of learners will be pre-conditioned by their use of technology to drive changes in pedagogy in educational institutions and that these changes will include aspects of collaboration, particularly team work and peer-to-peer learning.

Table 1: University types.

	University A	University B	University C	University D	University E
Founded	Founded 19th Century	Founded 1970s (Polytechnic) university status in 1992	Founded 1970s	Founded 1970s	Founded 21st Century from university college
Location	Large urban metropolitan	Large urban metropolitan	Large scale distance	Mid size campus outside small city	Mid size with multi-site, small towns
Course units	English	Sociology	Science	Modern Languages	Journalism
	Bio-science	Information and Communication	Health and Social Care	Computing	Psychology
	Veterinary science		The Arts	Accounting and Finance	Social Work

The Research

This research which is the first pilot phase of a two year study took place in the spring of 2008 in five universities in the UK. The universities were selected to represent the main 'types' of university found in the UK system and 14 courses were surveyed across a range of applied and pure disciplinary and subject areas (see Table 1). A questionnaire of first-year experiences of e-learning developed by the research team was administered in all five participating institutions. The instrument sought to collect baseline information about some of the key aspects of the students' use of technology in their studies and consisted of four sections: demographic characteristics of the respondents, access to technology, use of technology in university studies in general and finally course-specific uses of technology.

A total of 596 first-year students completed the survey: 58.6 percent were aged between 18 and 20; 80.3 percent were studying full-time and 19.7 percent were part-time students. The survey was complemented by interviews with staff (n=10) and students (n=12) who were recruited from those surveyed

Table 2 summarizes key demographic characteristics of the respondents by university. In addition to differences in the subject areas that students studied, reported in Table 1, there were significant differences in a variety of demographic features such as gender, student age and nationality.

Table 2: Key Demographic Characteristics (% of the total)

	University A	University B	University C	University D	University E	Overall
Male	22.3	27.3	36.1	43.2	16.3	27.8
Female	77.7	72.7	63.9	56.8	83.7	72.2
UK Students	96.6	95.3	93.3	80.8	98.0	93.9
Non-UK Students	3.4	4.6	6.7	19.2	2.0	6.1
18-25 years	96.0	89.1	12.6	95.9	84.4	75.8
Above 25	4.0	10.9	87.4	4.1	15.6	24.2
Full-time	99.4	96.9	5.1	100.00	99.0	80.3
Part-time	0.6	3.1	94.9	0	1.0	19.7
Total	176	128	119	74	99	596

Overall 50.9 percent of students lived in student accommodation, 8.1 in shared student accommodation that is not student residence, 38.2 percent lived either in their own home or with a partner or parent and 2.7 percent lived in other kinds of residence. 26.0 percent of students had living accommodation located at the university, 32.7 percent lived 0 to 3 miles from the university, 17.7 percent living over 3 miles from the university and 12.0 percent were genuinely distance students, i.e. they lived away from the university.

Key Findings

The findings reported in this paper focus on student use of social networking and Web 2.0 communications technologies such as blogs and wikis. The significance of these technologies is that the Net generation arguments claim that an entire generation who have grown up with technology exhibit different preferences and report different communicative practices to older people. In total, 68.3 percent of the respondents in the sample participated in online social networks (e.g. Facebook, Bebo, MySpace) at least on a daily basis or more frequently, but there was a large variation in terms of frequency of use between different types of universities ($F_{(4, 587)} = 60.20$, $p < 0.001$) and students aged 25 years of age and under and older students ($F_{(1, 587)} = 332.23$, $p < 0.001$). For example, only 25.7 percent of University C students reported a daily usage of social networks compared to 90.5 percent of students at University D. Student age is a complicating factor in relation to University C as it has a significantly different age profile. However although University C students comprised a majority of (often older) students who have never used a social networking site, there were also considerable minority groups of students in other universities, e.g. 11.0 and 11.2 percent of students studying with universities A and B also reported not participating in social networking.

To clarify the nature of age differences the sample was split into four age bands – 20 years of age and under, 21 to 25 years of age, 26 to 35 years of age and older than 35 years of age. As was the case with previous comparisons, younger respondents reported more frequent use of social networking websites ($F_{(3, 584)} = 554.20$, $p < 0.001$), e.g. only 4.3 percent of those aged 20 and younger never used this technology compared to 78.5 percent of those aged 35 years of age and older. Amongst Net generation age students (25 and under) 81.7 percent used social networking on at least a daily basis, whilst only 5.1 percent 'never' participated in online social networks. In comparison 55.7 percent of students aged 26 years of age and older reported they had never participated in social networking sites and only 24.3 percent of them reported the frequency of usage reported by most younger students. At a superficial level it would seem that the Net generation hypothesis is confirmed in that use of social networks is highly sensitive to age.

Gender differences did not appear to be quite as pronounced and there were no statistically significant differences in terms of the frequency of participation in social networks ($F(1, 587) = 2.93$, $p = 0.09$). Female students tended to use social networking sites more frequently (sample mean of 3.83 compared to 3.60 for men) and fewer women had never used a social networking website compared to men, 15.5 percent compared to 21.3 percent. There were no significant differences in terms of the experience of using social networking sites between the two gender groups before joining university (Cramer's V = 0.30, d.f. = 1, p = ns), but women were more likely to increase their usage at university then men (Cramer's V = 1.50, d.f. = 1, $p < 0.001$).

The picture is further complicated because we can see significant variations in the use of technologies for social life and leisure and for study purposes. Patterns in student use of various technologies for social life and leisure were correlated with the use of the same technologies for study at statistically significant levels ($p < .001$). However, the relationships between the use of these technologies for study and leisure were not equally strong. Using Cohen's (1988) discussion of the strength of correlations the associations between the use of instant messaging (r = 0.54) and internet telephony (r = 0.52) for study and for social purposes and leisure can be described as strong. The correlations between the use of text messaging (r=0.42) and social networking sites (r=0.41), chat rooms (r=0.36) and virtual worlds (r=0.46) were at a moderate level and it was weak for the use of e-mail (r = 0.29). Further work is required to clarify what these relationships might mean as it is the ubiquitous technology, email that has the weakest relationship.

Students tended to choose some of the same technologies for study purposes that they were required to use on their courses, including some of the newer Web 2.0 communication tools (Table 3).

Table 3: Use of Web 2.0 Tools in University Studies.

	Chose to Use (%)	Required to Use (%)	Cramer's V (d.f. = 1)
Instant messaging	26.2	3.2	0.22***
Wikis (including Wikipedia)	44.7	10.7	0.31***
Social networking websites	30.4	4.0	0.22***
Blogs	7.7	5.0	0.34***
Virtual Worlds	1.2	0.7	0.27 (n.s.)

*** p < 0.001

However the differences in percentage of students who chose to use certain tools were quite considerable and blogs and virtual worlds were used far less often than tools which allowed access to learning resources or interpersonal communication. For example, 26.2 percent of students in the sample chose to use instant messaging in their studies, but only 3.2 percent of them were required to use this technology in their studies. 44.7 percent of the respondents used Wikis (including Wikipedia), while only 10.7 percent were required to use this technology and 30.4 percent reported using social networking websites whilst only 4.0 percent were required to do so. Interestingly, the usages of blogs were at similar levels: 7.7 percent of students used blogs in their studies and 5.0 were required to use this technology. Clearly students chose to use certain technologies in their studies even when they were not required to do so, although more data on how students specifically used social networking sites to support their studies is necessary. Because the Web 2.0 tools were not used for study to a similar degree and were only loosely related to requirements to use them these results suggest that some communicative practices from the world outside the university are influencing student practices in relation to learning.

The interviews we conducted also gave some detailed indications of the motivations that lay behind the statistics and the ways in which particular institutional and course factors influence student engagement with technologies. The student we report below was required to use a specific e-porfolio system PebblePad which she had found relatively difficult despite being given training. The course she was studying was vocational and had a relatively large proportion of older students. In terms of group work and collaboration much of the work that this student reported was informal working around course activities. For example:

> *Interviewer: Did you communicate or work with other students?*
> Sometimes because especially I found with the more mature students they hadn't got as much experience as us, the younger ones [laugh] I helped some of them with the computer and some of them helped me … In sociology we did a group presentation on slides, mainly it (communication) was email we didn't use 'phones. (Social Work student University E)

Interview data such as this can help us understand the course and institution specific character of some of the students' activity. This helps make our approach more sensitive to local conditions than general surveys of large student populations can be.

Conclusions

The work we have done in the initial study suggests that the claim that there is a single Net generation with distinct characteristics is exaggerated and lacks the detail that might be necessary to make it useful for informing the design of collaborative teaching and learning practices. However there do seem to be age related changes taking place and these are strongly linked to social networking and the use of a range of new communications technologies. To investigate the relationships that might be emerging we are embarking on a second phase of surveys with a longitudinal dimension. This research began in October 2008. We are also going to conduct a further set of interviews and supplement these with a set of cultural probes based on the Day Experience Method (Riddle and Arnold 2007).

Recently Bennett et al. (2008) have taken a critical stance in relation to the arguments about the Net generation. They argue that the discussion of the Net generation has the features of an academic ‘moral panic’. We would suggest that our data supports some of their arguments by pointing to internal differences within the Net generation. Selwyn (2008), basing his argument on survey evidence from UK students, has suggested that the new generation of learners are no more homogenous than were previous generations. In particular Selwyn points to the existence of gender differences and he notes that the gender divide he finds in the survey data does not necessarily follow the lines of division that might be expected from earlier research. What we can be sure of is that if there is indeed a Net generation we will need to know more of this kind of detail if we are to respond to the changes in our educational designs and practices.

Finally collaboration and collaborative learning did not seem to be a strong feature of the students experience at university and the kinds of social networking that was done was mainly informal and largely unrelated to formal learning. The survey does confirm results reported elsewhere (Salaway et al 2008) that there are important changes taking place related to age and they are focused on the use of social networking technology

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How Does Students' Motivation Relate to Peer-Moderated Online Interactions?

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Abstract: Motivation has been recognized as a crucial factor that influences learning success. However, little research as addressed students' motivation in peer-moderated online interactions. This study conducted a content analysis of online discussions to discover how students' motivation relates with their interaction and knowledge construction in peer-moderated online discussions. The results indicate that intrinsic motivation was significantly correlated with students' elaboration processes and knowledge transfer. However, no significant correlation was observed between intrinsic motivation and students' moderation behaviors. The findings suggest that instructional designers and teachers in online classes should integrate strategies to promote students' motivation, and more importantly, they should scaffold student moderators to achieve meaningful learning in peer-moderated online discussions.

Introduction

Asynchronous online discussions have been integrated and are gaining popularity in distance learning. Asynchronous online discussions use networked computers to support the communication and interaction among learners and facilitate sharing and distributing knowledge and expertise in a learning community (Koschmann, Hall, & Miyake, 2002). Most contemporary course management systems, e.g., Blackboard, WebCT, Moodle, and Desired2Learn, have incorporated a component to facilitate asynchronous online discussions.

However, Bromme, Hesse, & Spada (2005) noted that in order to achieve high-quality online discussions, students must overcome three barrier-presumptions including (1) the establishment and maintenance of motivation to cooperate and communicate, (2) the mutual construction of "meaning" and the exchange of information in groups, and (3) the establishment and maintenance of structure in social interaction. These three requirements pose an essential challenge to students that they must be willing to join in and invest considerable mental effort in collaborative learning activities and also persist in their motivation and cognitive engagement in online discussions over time. In many ways, newly designed environments that are adopted to achieve successful distance learning require students to be more motivated and self-regulated than do traditional environments due to the lack of face-to-face moderation of instruction (Blumenfeld et al., 1991). Therefore, the quality of online discussions heavily leans on learners' motivational development toward computer-supported collaborative learning (CSCL) activities (Cheung, Hew, & Ling-Ng, 2008; Hakkarainen, et al, 1999; Author, DeBacker, Ferguson, 2006). Consequences directly related to students' lack of motivation include low levels of participation (e.g., Mazzolini & Maddison, 2003), insufficient peer referencing (e.g., Hewitt, 2005), superficial interaction (e.g., Weinberger, 2003), and unwillingness for building joint efforts (e.g., Grasel, Fischer, Bruhn, & Mandl, 2002).

Motivation for online discussions

Motivation is the internal force that drives an individual to engage in a particular behavior. It is believed that motivation influences students' learning decisively; that is, a learning behavior will not occur unless it is energized (Reeve, 2005). Student's motivation is a continuum that ranges from intrinsic motivation where a student takes action for the fun or challenge involved in the task to extrinsic motivation where the drive for a student to take an action includes seeking external stimuli or rewards, or avoiding pressure or punishment (Deci & Ryan, 1985; Lepper, 1988; Ryan & Deci, 2000b). Intrinsic motivation emerges spontaneously from internal tendencies (e.g., enjoyment) and can motivate behavior even without the aid of extrinsic rewards or environmental controls. Students with high intrinsic motivation demonstrate greater persistence (Li, Lee, & Solmon, 2005), better ability to cope with failure (Ryan, Connell, & Grolnick, 1992), more positive self-perceptions (Ryan & Connell, 1989), and higher quality task engagement (Ryan & Deci, 2000a).

Often times, students' school activities are driven by extrinsic motivation (e.g., grades, instructor's requirement, etc.) (Rovai, 2007). Being extrinsically motivated might result in low-level of participation and cognitive engagement in CSCL events. Wan and Johnson (1994) found that university students contributed less than one message per week in online discussion forums due to the fulfillment of the course requirement. Author and his fellows examined the relationship of students' intrinsic motivation and their participation in online discussions. They found that students' intrinsic motivation was significantly correlated with their online discussion participation meaning students who had high-level of intrinsic motivation demonstrated higher participation rate than those with low-level of intrinsic motivation. Intrinsically motivated students demonstrated twice to three times higher participation rate than those who are extrinsically motivated (Author, DeBacker, & Furgerson, 2006; Author & Durrington, 2007).

Blumenfeld, Kempler, and Krajcik (2006) suggested four determinants of motivation in CSCL. Their discussions, consistent with the Technology Acceptance Model and Self-Determination Theory, argued that perceived value, competence, relatedness, and autonomy are critical aspects that influence students' motivation in CSCL. The Technology Acceptance Model, which was created to explain and predict users' acceptance of new technology, suggests that the perceived value is one of the major determinants of users' motivation to accept and use a technology (Davis, 1989). Perceived value is the degree to which a person believes that using a particular information system would enhance their learning or task performance. It directly impacts not only a person's interactivity in online communication, but also his/her motivation toward using an information technology. Self-Determination Theory (SDT) identifies three innate psychological needs of intrinsic motivation – autonomy, competence, and relatedness (Ryan & Deci, 2000a). Autonomy refers to the need individuals have to determine their own behavior and to be free to act on their own volition (Baumeister & Leary, 1995; Reis, 1994). Competence refers to the need individuals have to feel successful in their attempts to understand and master their environment (Harter, 1978; White, 1963). Relatedness refers to the need individuals have to relate to others in ways that reinforce their feelings of emotional security and belonging (deCharms, 1968). Different effects on these three needs will result in different levels of intrinsic motivation. The groundwork for facilitating intrinsic motivation is supporting students so that they can improve their perceived value of CSCL and satisfy their needs for autonomy, competence, and relatedness.

Learning in online discussions

Social constructivists believe that human beings are unique and capable of constructing cognitive systems that interpret experiences with objects and other persons (Piaget, 1954), and learning is situated in a cultural context (Brown, Collins, & Duguid, 1989; Clancey, 1997; Lave & Wenger, 1991). This knowledge construction is a social and dialogical process in which different perspectives are incorporated (Pea, 1993). According to this view of knowledge construction, learning environments should encourage active participation, interaction and dialogue to provide students with opportunities to engage in a process of mutual knowledge construction. Therefore, many online classes have switched the major learning activities from reading Powerpoint slides to participating in asynchronous online discussions where students interact with one or more peers to solve a given problem or share experiences by reading and writing messages in a discussion board. Student online discussions provide the primary means for distance-learning students to exchange ideas, share multiple perspectives, and clarify understandings. However, researchers also raised some critical questions: Do students really learn in these online discussion activities? How do we know if learning really occurs (e.g., Dennen, 2008)?

A notion consistent with this social constructivist perspective believes that learning is thought to take place on two levels of interaction (Vygotsky, 1978): (1) an individual learner by interacting with others, and (2) in an interaction with self. At the first level, students interact with others to build social connections, form learning communities, and share information and experiences on a common topic or a problem (Weinberger & Fischer, 2006). Knowledge construction actually starts at this level, but does not stay here. In order to promote meaningful learning in CSCL, students have to integrate the knowledge into their own mental structures (e.g., schema). This knowledge integration is realized through elaboration processes. Two views of the elaboration processes are involved in CSCL. One focuses on reaffirming what students already understand by elaborating their prior knowledge and experiences, and the other focuses on adjusting participants' mental models to accommodate new knowledge or different perspectives through synthesizing ideas and elaborations from the group (Vygotsky, 1978; Dennen, 2008). Therefore, besides social interaction and sharing information, learning in CSCL can also be manifested through two different elaboration processes, which in this article we define them as egocentric elaboration and allocentric elaboration. Egocentric elaboration is the process that a student elaborates on a concept or idea based on his or her own experiences. Allocentric elaboration, on the other hand, is the process that a student contributes to collaborative knowledge construction by synthesizing other individuals' comments and collaboratively elaborating on a concept or an idea.

Researchers agreed that content analysis is a powerful approach to provide evidences of students' learning in online discussion activities. It can unveil the dynamic patterns of interactions in the actual discussion discourse (e.g., Gunawardena, et al., 1997; Hara et al., 2000; Henri, 1992). Henri (1992) and Hara et al. (2000) developed an analytical framework based cognitive information processing model. They focused on students' social, cognitive and metacognitive perspective and categorized the online discussion contents based on Bloom's taxonomy, which involves different levels cognitive activities from elementary clarification, in-depth clarification, to inferencing, judgment, and application of strategies. Gunawardena et al's (1997) analytical framework, on the other hand, focused on the process of knowledge construction. She believes that the knowledge construction in online discussion context involves five phases of development: (1) Sharing and comparing of information; (2) the discovery and exploration of dissonance or inconsistency among ideas, concepts or statements; (3) negotiation of meaning and co-construction of knowledge; (4) testing and modification of proposed synthesis or co-construction; and (5) agreement statements and applications of newly constructed meaning. Later on, Salmon (2000) further developed this model into a 5-step e-moderating model aiming to help training student tutors to effectively facilitate discussion groups. His model involves (1) access and motivation, which centers on welcoming participants and offering them technical support, (2) online socialization, which helps to establish a feeling of community, (3) information exchange, where learning is becoming the more prominent objective, (4) knowledge construction, where social negotiation and task-related engagement occurs, and (5) development, where participants reassess their own thinking and explore the social learning processes. In this study, we developed the *Online Learning Interaction model* that integrates the concepts from these previous analytical frameworks. It holds the social constructivist view of learning but also keeps students' cognitive perspective in consideration. This model is illustrated in the data analysis section. We hope through the content analysis students' interaction and learning patterns will emerge from the discussion corpus.

Peer-moderation in online discussions

In a successful online collaboration, the guidance of the instructor and the moderation of students are two key interventions that facilitate online learning discussions (Rovai, 2007). A peer-moderator can be defined as "people from similar social groups who are not professional teachers, helping each other to learn, and learning themselves by teaching" (Topping, 1996, p322). This moderator may start or participate in discussions, provide timely feedback to difficult questions, identify the key issues remaining to be addressed, or make explicit suggestions for further development. Vygotsky (1978) suggests that a student's cognitive development can be explained by the concept of 'zone of proximal development', which is the difference between what a learner can do without help and what he or she can do with help. Research has documented that peer-moderation is an effective strategy to support cognitive development in online discussion activities (Smet, Keer, & Valcke, 2008). With support provided by peer-moderators, students progress from zone to zone of their cognitive development (Jaramillo, 1996). Moreover, implementing the strategy of peers supporting one another as compared to staff support entails beneficial effects on students' motivation (Neville, 1999). With peer support, students may perceive that online discussion as a useful and valuable way to communicate and get information, which may lead more willingness to continue to participate in this type of discussion (Author, DeBacker, & Ferguson, 2006). However, the body of research mainly focused on how peer-moderation can influence students' motivation and learning. Little research examined how moderators' motivation levels can impact their moderation performance, and consequently influence their peers' online interaction and learning.

Method

Purpose of the study

Studies indicated that students' motivation, especially intrinsic motivation impacts their participation rate in online discussions. However, in order to examine if motivation really impacts learning, two critical issues need to be addressed: whether learning occurs in online discussions and how students' motivation impacts their learning behavior. This study conducted a content analysis of online discussions aiming to understand the nature of CSCL and discover how students' motivation impacts their interaction and knowledge construction in peer-moderated online discussions. This study used SDT as the theoretical framework and was guided by the following questions: (1) What are the patterns of students' interaction and knowledge construction? (2) Does students' motivation have a relationship with these interaction patterns? (3) Does students' motivation have a relationship with student moderation? How does moderation impact their peers' knowledge construction?

Participants

The participants were 18 graduate and 6 undergraduate students from two sections of an online instructional technology course at a large Southeast University. The main goal of this course is to promote students' understanding of different educational theories and methods, and different approaches of integrating technologies for meaningful learning. The instructional activities were designed to promote students' higher-order thinking (e.g., knowledge transfer and application). Students were also desired to collaborate with peers and pursue collaborative knowledge construction. Students participated in weekly online discussions, which was a significant portion of the class and accounted for 30% of students' final grade in the course. Students were assigned into smaller groups of 6 to 8. Each student moderated a chapter discussion for a designated week within his or her own group. During the course, students joined in the discussions to share information and contribute to knowledge construction. The instructor observed students' discussion activities and supported the discussion when needed. Participants completed survey questionnaires measuring demographic information, attitudes toward the class and the instructor, and intrinsic motivation related to participating in online discussions at the end of the semester. All the online discussion activities in this course were archived in a

WebCT system where the instructor created discussion topics and forums at the beginning of the semester. The survey questions were delivered through an online survey system designed and developed for this research.

Measures

The survey questionnaires included instruments measuring motivation and students' attitude toward the class. Students' motivation is measured by Deci and Ryan's Intrinsic Motivation Inventory (IMI), which is a multidimensional measurement device intended to assess participants' subjective experience related to a target activity (Self-Determination Theory WWW). The IMI was modified to specifically address students' motivation in participating in the online discussions in this study (Author, DeBacker, & Furgerson, 2006). The revised IMI measured 5 variables related to students' intrinsic motivation including (a) 8 questions measuring enjoyment in online discussion, (b) 7 questions measuring perceived value of the online discussion, (c) 8 questions measuring feelings of autonomy in regard to the online discussion, (d) 6 questions measuring feelings of competence in regard to the online discussion, and (e) 8 questions measuring feelings of relatedness to student peers in the online discussion. As suggested by the IMI scale description (Self-Determination Theory WWW), the enjoyment subscale of IMI is considered the self-report measure of Intrinsic Motivation. Since the primary goal of students' participation in the online discussion board is content specific, and students were not encouraged to discuss non-content related topics, this study did not differentiate student motivation for discussion from their motivation related to the content area. Students' attitude toward the class in general was measured by 6 Likert style items created for this study. Means, standard deviations, internal consistency coefficients, and sample items for all scales used in the study can be found in Table 1.

Table 1: Means and Standard Deviation of Motivation and Attitude Variables

Variable	Mean (SD)	α	Sample Item
Enjoyment*	4.64 (1.56)	.94	If I participate in this online discussion, I will be thinking about how much I enjoy it.
Perceived Value	5.14 (1.61)	.95	I believe that participating in this online discussion can be of some value for me.
Autonomy	3.48 (1.70)	.89	I believe I have some choice about participating in this online discussion.
Competence	5.11 (1.21)	.76	I believe I am pretty skilled in the online discussions that allow me to share my knowledge and experiences.
Relatedness	4.06 (1.31)	.86	I'd like a chance to interact with the people in the online discussions more often.
Course Attitude	5.58 (1.07)	.81	How do you believe you will like the instructor in this class that you are taking?

* *The enjoyment is considered the self-report measure of Intrinsic Motivation.*

Data collection and analysis

Data for this study included the transcripts of the electronic discussions and the self-reported survey results. The transcripts were organized and transformed to text files with all the identity information being removed. The transcripts were collected to provide information about the patterns of online learning interactions.

In agreement with Beers, Boshuizen, Kirschner, and Gijselaers (2007), the authors of this study held the belief that a new online collaborative learning research project, when focusing on a different theoretical framework or a different research purpose, will generally require new coding themes for analysis. Therefore, rather than using an existing content coding themes, we analyzed the online interaction transcripts using a self-developed analysis schemes - *Online Learning Interaction Model*. This model synthesized the three representative content analysis schemes in the distance education literature: the model of Henri (1992) that analyzes the transcripts of discussions based on a cognitive approach to learning, and the model of Gunawardena et al. (1997) and Salmon (2000) that examines the transcripts of online interactions from a social constructivism perspective. In this model, the unit of analysis is "thematic unit" (Henri, 1992). Each unit was then classified into one of the eight analytic categories under three dimensions, outlined as the following:

Table 2: Online Learning Interaction Model

Code*	Interaction Category		Definition
S	Social Interaction		Having the indicators of greetings, comments without elaboration (e.g., "I agree with you"), personal life, and emotional expressions.
K1	Knowledge Construction	Sharing information	Simply adding facts, opinions, or questions without elaboration
K2		Egocentric elaboration	Elaborating one's own arguments/concepts/problem solutions
K3		Allocentric elaboration	Comparing and synthesizing peers' multiple perspectives
K4		Application and Transfer	Planning future application of new knowledge or proposing in-field application strategies
L1	Regulation of Learning	Coordination	Teamwork planning and coordinating for cooperation and/or collaboration
L2		Reflection	Self-evaluation and self-regulation on learning process
L3		Technical issues	Questioning and answering on technological problems or assignment clarification

* *Codes will be used in the following discussions to indicate Interaction Categories.*

All the discussion contents were exported from WebCT system along with all the meta information (e.g., timestamps, authors, and etc.). The two researchers scheduled and met in a 4-hour training session in which they together studied the analytical framework, coded two training data sets, and discussed the differences until reached a 100% agreement. Then the researchers blind-coded all discussion transcripts independently. Inter-rater reliability was calculated (*Kappa* = .92). The researchers also discussed the coding differences and reached a 100% agreement.

Results

Online learning interaction patterns

During the 16-week semester, students participated in 10 chapter discussions and generated a total number of 1462 thematic units. Among them, 44% were identified as K1 category (n = 645); 20% as K2 category (n = 294); 19% as S category (n = 279); 12% as K3 category (n = 182); only about 2% were identified as L2 category (n = 29), 2% as L3 category (n = 27), and 1% as K4 category (n = 9); and only 3 thematic units were identified as L1 category. These results indicated that a significant proportion of students' interactions for knowledge construction were at a superficial level by simply adding facts, opinions, or asking questions. Students were heavily involved in individualistic elaborations on concepts and opinions from personal experience and theoretical references. There were relatively less efforts put in collaborative elaborations. In addition, students performed online interactions for social purpose in which they greeted each other, built social relations, or expressed their personal emotions. Little efforts were observed for knowledge application and transfer, collaboration coordination, reflection, or resolving technical issues.

A series of correlation analyses was performed among the learning interaction variables. The results indicated that S was significantly correlated with K1 (r = .89, p < .01) and K3 (r = .62, p < .01). K1 was significantly correlated with K2 (r = .37, p < .05) and K3 (r = .58, p < .01). L2 was significantly correlated with K3 (r = .38, p < .05) and K4 (r = .62, p < .01). L3 was significantly correlated with S (r = .55, p < .01), K1 (r = .52, p < .01), and K2 (r = .42, p < .05). No significant correlations were found between L1 and any variables of interest. The results indicated that students with more social interaction were more likely to share information and were more likely to compare and synthesize others' comments and involve in collaborative elaboration process. Students who performed higher-level cognitive engagement (e.g., K2 and K3) were also likely to share facts and opinions. In addition, students who performed reflection activities were also likely to engage in the highest levels of cognitive activities (e.g., allocentric elaboration and application).

Relations between motivation and knowledge construction

A series of correlation analyses was performed between learning interaction variables and self-reported motivation and attitude variables. The results indicated that intrinsic motivation was significantly correlated with K2 (r = .40, p < .05), K3 (r = .35, p < .05), K4 (r = .36, p < .05), and L3 (r = .42, p < .05). Perceived value was significantly correlated with S (r = .45, p < .05), K1 (r = .47, p < .05), K2 (r = .44, p < .05), K3 (r = .39, p < .05), and L1 (r = .35, p < .05). Relatedness was significantly correlated with K3 (r = .44, p < .05). Competence was significantly correlated with S (r = .56, p < .01), K1 (r = .57, p < .01), K2 (r = .45, p < .05), K3 (r = .51, p <

.01), and L3 ($r = .50$, $p < .01$). Course attitude was significantly correlated with S ($r = .42$, $p < .05$), K1 ($r = .44$, $p < .05$), K2 ($r = .50$, $p < .01$), K3 ($r = .47$, $p < .05$), K4 ($r = .36$, $p < .05$), and L3 ($r = .47$, $p < .05$). No significant correlations were found between perceived choice and any variables of interest. The results indicated that students' intrinsic motivation predicted their knowledge construction, especially higher-level cognitive engagement (e.g., K2, K3, & K4). When students perceived the online discussion activities are valuable, and/or when students perceived themselves competent in the learning tasks, and/or when students had positive attitude toward the class and the instructor, they were more likely to engage in higher-level online discussions. In addition, if students had strong a sense of relatedness to the learning community, they were more likely to involve in collaborative elaboration processes.

Motivation and discussion moderations

In order to explore how students' motivation was related to their online interaction when they were in a moderator position, a series of correlation analyses was performed between moderator's motivation and attitude variables and their moderation activities. The results indicate that perceived value was significantly correlated with S ($r = .36$, $p < .05$). Relatedness was significantly correlated with S ($r = .36$, $p < .05$) and K3 ($r = .46$, $p < .05$). Perceived competence was significantly correlated with S ($r = .45$, $p < .05$), K1 ($r = .46$, $p < .05$), K3 ($r = .37$, $p < .05$), L2 ($r = .43$, $p < .05$) and L3 ($r = .38$, $p < .05$). Course attitude was significantly correlated with L3 ($r = .43$, $p < .05$). No significant correlations were found between intrinsic motivation, autonomy, and any learning interaction variables. The results indicated that if a moderator perceived the online discussion activities were valuable, and/or perceived himself/herself to be competent in the learning tasks, and/or had strong relatedness to others, he/she was more likely to engage in social interactions. If a moderator had strong sense of relatedness and strong competence, he/she was more likely to involve in collaborative elaboration processes. In addition, the significant correlation of perceived competence with five of learning interaction variables indicates the importance of perceived competence for peer-moderators.

More important is the examination on whether the moderation affected students' learning. Although student moderated the discussions at most time, the instructor's activities might have been influenced students' interactions in the discussion activities. Therefore, correlation analyses were performed between student moderators' (-M) and student peers' (-P) interaction variables, and between instructor' (-I) and student peers' (-P) interaction variables. The student-student correlation matrix indicated that S-M (1) was significantly correlated with S-P ($r = .86$, $p < .01$), K1-P ($r = .81$, $p < .01$) and K2-P ($r = .79$, $p < .01$). K1-M was significantly correlated with S-P ($r = .82$, $p < .01$), K1-P ($r = .79$, $p < .01$) and K2-P ($r = .77$, $p < .01$). K3-M was significantly correlated with S-P ($r = .80$, $p < .01$), K1-P ($r = .74$, $p < .01$) and K2-P ($r = .68$, $p < .01$). L2-M was significantly correlated with S-P ($r = .36$, $p < .01$), K3-P ($r = .40$, $p < .05$) and L2-P ($r = .47$, $p < .05$). L3-M was significantly correlated with S-P ($r = .51$, $p < .01$) and K1-P ($r = .45$, $p < .05$). The instructor-student correlation matrix indicated that K4-P was significantly correlated with S-I ($r = .61$, $p < .01$), K2-I ($r = .51$, $p < .01$), K3-I ($r = .51$, $p < .01$), K4-I ($r = .81$, $p < .01$) and L2-I ($r = .81$, $p < .01$). L2-P was significantly correlated with S-I ($r = .44$, $p < .05$), K2-I ($r = .51$, $p < .01$), K3-I ($r = .44$, $p < .05$), K4-I ($r = .83$, $p < .01$) and L2-I ($r = .83$, $p < .01$). The results indicated that peer-moderators' knowledge constructions (S-M, K1-M, & K3-M) were positively associated with students' lower-level knowledge constructions (S-P, K1-P, & K2-P). Student moderators' reflective interactions were positively associated with student peers' social interaction, collaborative elaboration, as well as their reflections. On the other hand, the instructor's moderation (S-I, K2-I, K3-I, & K4-I) was positively associated with students' higher-level knowledge constructions (K4-P) and their reflective interactions (L2-P).

Discussions and Conclusion

This study examined the relationship between students' motivation and their online interactions in a distance learning class. Previous studies found that students' motivation were significantly correlated with their participation rates (e.g., number of messages posted or number of times logged in), but failed to take the discussion content in consideration (e.g., Hew & Cheung, 2008; Author, DeBacker, & Ferguson, 2006). This study took the online discussion contents into account and revealed interesting patterns of students' interaction for knowledge constructions. Through the semester, students performed online learning interactions that contribute to the knowledge construction at different levels from simply sharing facts, opinions, and experiences, to elaborating one's own or others' ideas, to applying and transferring knowledge in practices. However, the volume of these levels differed: the lower level categories had larger volumes than those of higher-level categories. This finding supports Salmon's five-step model, which believes that the online interaction process starts from the lower-levels interactions, e.g., assess and motivation, and online socialization, builds upon them, and evolves gradually to the higher-levels, e.g., knowledge construction and development (Salmon, 2000; Smet, Keer, & Valcke, 2008).

The study results indicate that motivation played an important role in students' online interaction. At the whole class level, intrinsic motivation and perceived value had significant correlations with both egocentric and allocentic elaboration processes of knowledge construction. The study also indicates that the inner psychological variables related to intrinsic motivation predict students' knowledge construction. Specifically, perceived competence was positively associated with the volume of interactions for sharing information as well as elaborations. Relatedness was positively associated with collaborative elaborations. In addition, we found that highly motivated students demonstrated not only high cognitive engagement, but also persistence in their engagement throughout the semester, whereas low motivated students were the contrary. These results support Author et al. (2006, 2007) finding that intrinsic motivation predicted students' participation rate manifested by the posting numbers. This study provided further evidences that intrinsic motivation predicts not only students' participation rate, but also their learning processes as indicated by the content analysis of their online discussion scripts. The results indicate perceived value was associated to information sharing interactions, whereas intrinsic motivation was associated to application and transfer. One step further, looking into the moderated discussion sessions, we found that perceived value and relatedness were related to students' moderation behaviors. Moderators' perceived competence seemed to be an importance factor that may predict students' moderation behaviors at all different knowledge construction levels.

The study findings suggest that facilitating intrinsic motivation and perceived value should be considered in instructional design for online collaborative learning. Teachers should find ways to promote students' intrinsic motivation. Literature suggests that purposeful CSCL design interventions (such as, creating optimal challenging tasks, enhancing belongingness of learning community, etc.) may increase students' intrinsic motivation for learning (Raffini, 1996). The study finding also suggests that in order to promote interactions for knowledge application and transfer, teachers should help students to understand the true value of the online collaborative learning in order to initiate online interactions. This suggestion is similar to what Hakkarainen et al (1999) stated in their study that teachers could have a positive influence on students' learning when they emphasize the inherent importance and value of the learning materials. According to SDT, three innate psychological needs are keys to promote intrinsic motivation (Ryan & Deci, 2000a). The study findings suggest that perceived competence is a crucial factor that impacted students' online learning interaction as well as their moderation behaviors in collaborative learning. Therefore, instructional design for CSCL should find ways to promote students' perceived competence in the learning activities. With higher perceived competence, students will not only show more willingness to share information with their peers and collaborate with others to elaborate on instructional tasks, but also show better performance in moderating online discussion. The findings also provide evidences that students' perceived relatedness to their peers correlates with their contribution in online discussions. It is consistent with previous research studies that recommend teachers should foster the development of trust relationships among individuals in online collaborative learning (e.g., Cheung, et al, 2008; Hew & Hara, 2007).

It is important to note that no significant correlations were found between students' intrinsic motivation and their moderation behaviors, which indicates that highly motivated students did not necessarily provide a better-quality moderation. One possible reason might be that students might not have had the adequate skills to facilitate a successful online discussion even when they were highly motivated. Therefore, instructional design for peer-moderated online discussions should consider developing students' moderation skills. Many research studies suggest that purposeful training sessions before moderation activities, moderation guidelines, instructor's modeling of moderation, or job aids should be considered to ensure successful online discussions (e.g., Hew & Cheung, 2008; Smet, Keer, & Valcke, 2008).

Besides knowledge construction, students also performed social interactions and reflective behaviors. Interestingly, social interactions had significant correlations with information sharing and allocentric elaboration behaviors. This finding supports Rovai's (2007) argument that the social component of online interaction is vital for the success of online collaborative learning. Social interactions enable students' feeling of social presence and enhance self-awareness and awareness of others in the learning community (Cutler, 1995). Previous research suggests social interactions increase students' willingness to participate in collaborative knowledge constructions, such as sharing information and allocentric elaborations (Garrison & Anderson, 2003; Gunawardena & Zittle, 1997). The study also found that reflective interactions influenced students' higher-level knowledge constructions. Reflective interaction can be viewed as a type of metacognitive behavior, namely self-awareness. Self-awareness is the awareness students have over their own cognitive activities (Schraw & Moshman, 1995). Many studies have documented that self-awareness promotes higher-level learning (e.g., critical thinking, knowledge transfer, etc.)(King, 1991; Zellermayer, et al., 1991). Kauffman et al. (2008) found that prompting online students with reflection prompts could be an effective technique for improving problem solving and achievement. To sum up this point, our findings suggest that although content-related knowledge constructions are important, students' social interaction and reflective activities should not be ignored and discouraged because these interactions will facilitate content-related knowledge construction processes. As such, instructional design for online collaborative learning activities needs to improve social presence and promote metacognitive activities.

Our findings indicate that student-moderations were positively associated with peers' lower-level knowledge construction whereas instructor-moderations predicted peers' higher-level knowledge construction. It seems to indicate that students' moderation are important to the initiation of online discussions, but their moderation might not lead to high-quality discussions without support from the instructor. This finding supports Rovai's (2007) argument that instructors' presence promoted students' cognitive engagement. The study seems to indicate that moderators' reflective comments might have had been served as reflective prompts that prompted students' metacognitive behaviors. It is similar to the findings in Hakkarainen et al. (1999) that suggest teachers' metacogntive-like participation in asynchronous online discussions guided the students toward deepening inquiry.

Limitations of the study

The present study has a number of limitations. This study was conducted in a particular educational setting with a small sample size, which might have impacted the power of the statistical analyses. Future research should use a larger sample size to see if similar findings can be replicated. This study used mainly a quantitative approach. In order to increase the validity of interpretation of the results, follow-up research could consider including interview data with students and instructors to study their perceptions of their learning processes in online collaborative learning. Despite these limitations, the present study revealed interesting findings on the impacts of intrinsic motivation on students' participations and moderations in online collaborative learning activities. These findings draw practical implications in designing and facilitating successful online learning.

Endnotes

(1) S-M indicates student moderators' (-M) social interaction (S). The same acronym method was used to indicate other categories of learning interaction.

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Relay Race of Practice: Integrating Technological Tools into Teaching and Learning Scenarios

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Abstract: Even though integrating technological tools into teaching and learning scenarios is an agreed upon goal it is still far from being fully implemented. This study examines a process of integration of a technological tool, to which a group of teachers participated. The technological tool was developed to enhance dialogism and argumentation, in one Grade 9 class. The question we focused on concerns whether the technological tool used by each teacher for a specific subject matter became integrated in teaching and learning practice across disciplines. Data included 22 discussion maps in five activities by different teachers. The analysis focuses on two dimensions of use of the technological tool: its form and its function. The findings show a process of appropriation of the technological tool could be detected along the five activities. This appropriation could be seen through the increase of arguments and challenges, the growing reference to each other's ideas, and capitalization of previous arguments in follow-up arguments. The results of this study stress the importance of the participation of teachers in the same teacher training and shows that appropriation of norms afforded by a tool are instigated by their participation in two activity systems stimulated by the same technological tool.

Introduction

Integrating technological tools into teaching and learning scenarios has been an important goal (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004), but still far from being fully implemented. Technological tools such as MS-Word, PowerPoint are used for simple goals and are not utilized for promoting learning in their daily work (e.g., Cuban, 2002). It appears that teachers consider the use of technologies as a waste of time that time should be devoted to the teaching of subject matter. In addition, teachers are concerned about being perceived as incompetent by their students.

Pedagogical solutions often focus in two main areas: One concerns the adoption of known technological tools (chat, forum, etc.) for teaching and learning purposes (Herring, 2004). The second concerns efforts to develop innovative pedagogical technological tools and assimilate their use in a design research program (e.g., Fishman, Penuel, & Yamaguchi, 2006). This research belongs to the second category. The integration of innovative technological tools into teaching scenarios can be effectively developed through teacher training programs. Those programs typically include the combination of a specific content in a subject matter with the articulation of a pedagogy which incorporates to the use of a tool especially tailored for reaching a goal expressed by the developers. However, the use of such tools in classrooms often differs from the initial intention of the programs' developers (Squire, et al., 2003). An innovative approach has evolved in the EC-funded KP-Lab (KP-Lab FP6-IST-2004, 27490) teachers' training program (Engeström, 2003, Schwarz, & de Groot, 2007). Teachers are required to assume responsibility for the integration process of technological tools. The program introduces the teachers to many open or mediating technological tools (instead of specific tool) and provides them with technological and pedagogical support from expert teachers, in order to address difficulties arising while working with such tools (e.g., copy-paste habits). Furthermore, the teachers are required to apply what they have learned during their professional training in their own classrooms by designing learning units which make use of one of the tools presented in the program and implementing them with their students.

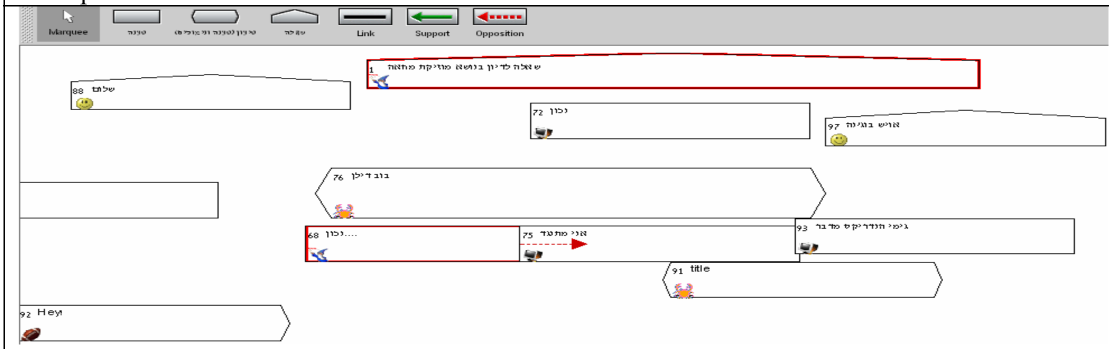
The aim of this study is to accompany the integration process of a technology. Our question is whether the technological tool used by each teacher for a specific subject matter became integrated in teaching and learning practice across disciplines. The answer to this question will shed some light on the teaching and learning processes that take place in the same class. We will show that when the technological tool is used by all teachers of the same class, the intentions of the developers are progressively instilled in the learning /teaching culture in school. This instillation is communal and occurs across disciplines. At the end of the paper we will show the crucial part of the in-service teachers program played to turn teachers' participation in the same activity system a trigger for appropriation of the norms afforded by the tool by the students in the second activity system that constitutes the class.

Methodology

Research plan

The present research focuses on the implementation of the technological tool in the classrooms, as a result of an in-service teacher training program. Three of the teachers in this program taught a different subject matter (Bible, Civics and History of Music) in the same class. They were invited to design learning units capitalizing on the same technological tool – Digalo. Digalo is a technological tool developed to enhance dialogism and argumentation by providing an argumentative map – a graphical representation personalized argumentative moves. As discussants are invited to discuss an issue, each discussants chooses a shape from the argumentative ontology provided. The upper bar in Figure 1 shows an ontology which includes *claims* (rectangles), *arguments* (hexagons), *questions* (trapezes), and three kinds of arrows (neutral, support and opposition. The discussant chooses a shape, inscribes its title and enters its content within the shape. He/she generally connects his/her intervention by an arrow to others' interventions. The argumentation map progressively produced is a group product, which can be capitalized on in further learning activities (Schwarz, & de Groot, 2007). Figure 1 presents examples of argumentation maps (a detailed discussion on this figure is in the finding section).

Example from the first session



Example from the fifth session

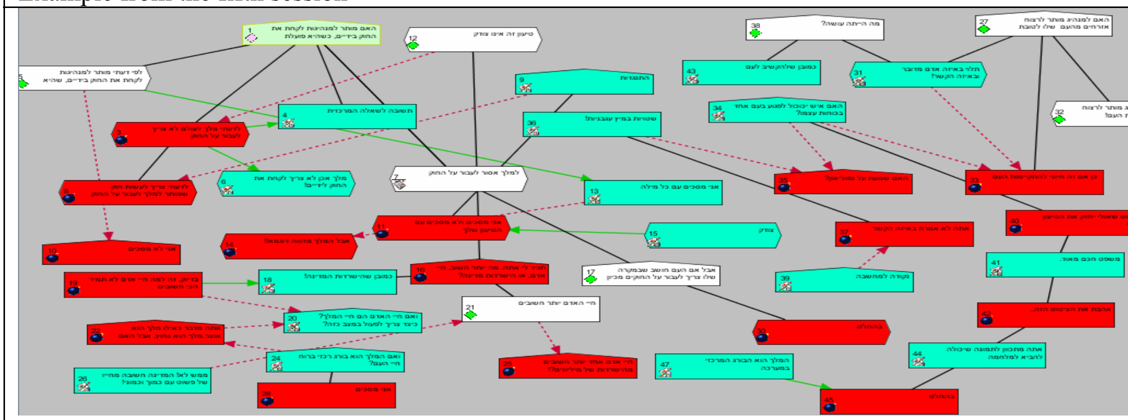


Figure 1. Argumentation maps

In the present study, the three teachers of the same Grade 89 class preferred to use technological tool in small group of students, the class was divided in 4-5 groups, so that each student worked with the technological tool several times during the experiment. Table 1 presents the research plan.

Table 1. Research plan

	1st session	2nd session	3rd session	4th session	5th session
Subject matter	History of Music	Civics	Bible	Civics	Bible
Technological tool	Digalo	Digalo	Digalo	Digalo	Digalo
Participants	1/3 of the class students	½ of the class students	½ of the class students	½ of the class students	½ of the class students

Data collection and analysis

Data were collected by 22 discussion maps. They included 295 shapes and 666 links. In addition we undertook observations during the five lessons during which Digalo was used and in four other lessons. Also participatory observations during the teachers training program were undertaken. In order to trace the use of Digalo in the class we focused on two dimensions, the *form* and the *function* of use.

Integration of the technological tool into classroom practices

Form of use

This dimension expresses the different options used by discussants. We found change in the use of options the tool offers: 1) Concerning shapes, at the beginning 85% of the created shapes were deleted, in the last enactment approximate 90% of the shapes created remained (with their contents) until the end of the discussion; 2) Concerning connections, at the beginning of the discussion, the use of connections was rare and inconsistent. Later on, as the students became more familiar with Digalo most of the shapes were linked to more than one shape. Figure 2 displays the progression in the use of shapes chosen in discussions.

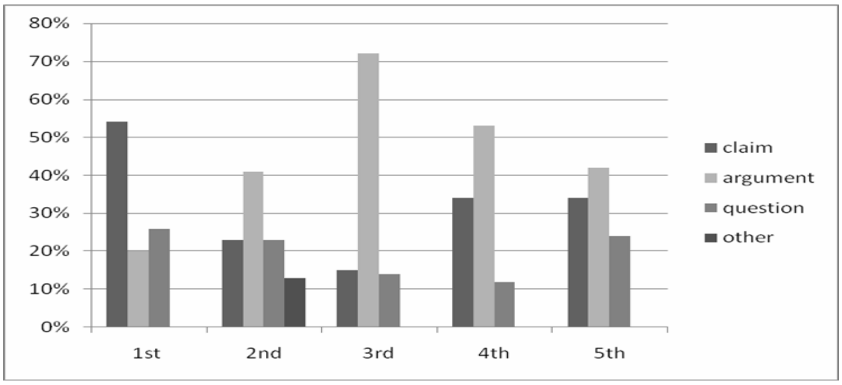


Figure 2. Ontological shape in the five sessions

The observations during the lessons in which Digalo was used showed that the teachers encouraged the students to use arguments rather than claims only. This fact fits the spirit of the in-service program according to which discussion should be reasoned. In the third session, as can be seen in Figure 2, this was the main selected shape. It means that the students chose to contribute to the discussion mainly with arguments. Over time, the students became more critical and chose shapes according to the progress of the discussion. An additional change relates to the questions-shape: at the beginning the questions were asked only by the teacher, in order to advance the discussion, but later on, the questions were raised also by the students that challenged their friends or asked them to explain themselves ("why do you think so?" Or "Isn't this a contradiction to your previous claim?").

Function of use

The function of use focuses on the quality and characteristics of the shapes and the connections. In order to examine the function of use of the shapes, a scale was elaborated:

1. *Closed* intervention: declaration, expressing position without mentioning other opinions. Does not include reference to the other.
2. *Open/linked* intervention: calls for a response/clarification (is not declared as a ruling or final point), linked to other responses (for example, by referring to other members), there is reference to the process
3. *Social* intervention: an intervention that does not refer to the activity at stake but expresses a way to socialize. These interventions include reference to other members without additional contents or emotions (e.g., "I think like X", "Great idea" or different kinds of curses)

Figure 3 displays the type of interventions that the students wrote during the electronic discussions. 588 interventions were analyzed (the titles of the shapes and the content they included were analyzed separately).

As can be seen, the types of interventions changed from the first to the fifth activity:

Closed interventions: There is a decline in these interventions. Contents analysis shows differences in their characteristics. At the beginning the interventions include mainly declarations of individual position (like – "my answer to the question is…"); Later on, there is evidence in the close interventions that the writer understands he/she is part of the group discussion ("I have already said my opinion, but I'll repeat it…").

Open interventions: These interventions increase over time. Contents analysis shows transition in the characteristics of the open responses: At the beginning it included mainly reference to previous answers (for example, : “I also think that…”); then it moves to call for response/ thinking (for example, “think again what will happen in case…”); And at the end, it included challenges in thinking of other cases (for example, “would you prefer to convert your religion and live or to…”)

Social interventions: There is a decline in such kinds of interventions. Contents analysis shows differences in the phrases characteristics. At the beginning it was social without contents (like “Hi all, how are you doing?”). It then moves to a social relation to an opinion “personal” (like “Response to Shai”); Social mapping (like “agree with Or”); At the end, there were Social comments promoting the discussion (like “Guys, if all would agree we will have no discussion”).

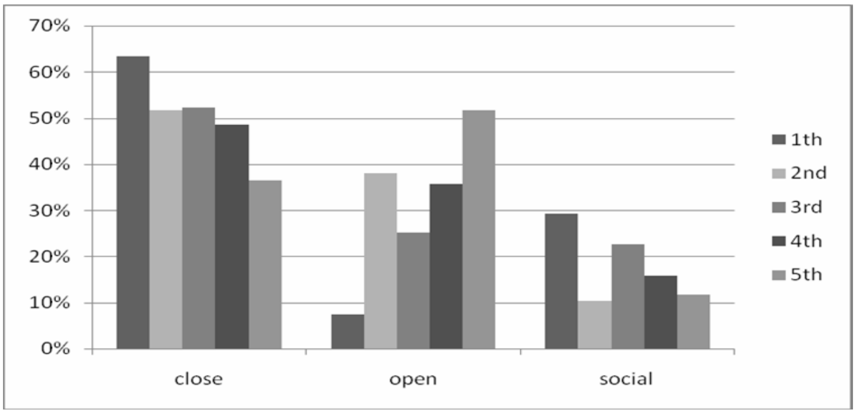


Figure 3.The types of interventions

The second element of function of use concerns the usage of connections. As we mentioned earlier, the amount of connections increased. Figure 4 shows changes in the use of connections.

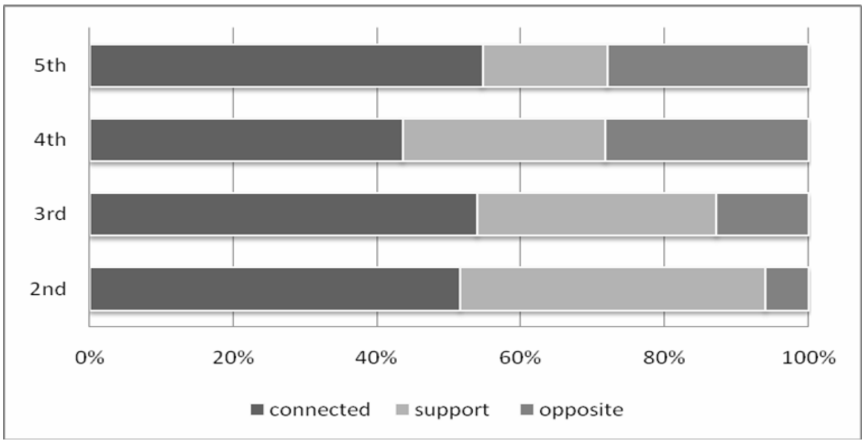


Figure 4. Types of connections

Note: This figure does not include the first session because it barely included connections (see Fig. 1).

In all sessions, half of the connections that the students chose to use were connections without taking position (e.g., agree or disagree). However, during the implementation lessons there was a transition from connections of support to connections of opposition that expressed resistance. In other words, students learned to resist to their friends interventions, a behavior that was a priori considered as inappropriate in class.

The argumentation maps presented in Figure 1 sketch a deep change in the classroom practices. In the first session the students carried poor discussion (not many shapes), each student expressed his/her opinion, mostly without referring to other students’ arguments (not many connections). Further discussions, however, were rich in content. Students referred to their fellow-students arguments and shaped/change their opinions accordingly.

Discussion

We brought in this short paper glimpses on the deep changes that the introduction of the Digalo tool instigated in classroom practice through five discussions. Productive discussions developed. They included: raising and challenging different arguments; referring to each other by raising arguments; and utilizing previous arguments in follow-up arguments. Analyses of the class discussions show also changes: a) From a technical presentation of the tool (use of form) to a pedagogical (use of function) presentation; and b) from emphasis on expressing position to emphasis on explanations and contribution to the discussion. The five integrated lessons of the same technological tool (Digalo) in the same Grade 9 point at an evolutional process. Although in these lessons, teachers, students and subject matter varied, it seems as if the evolution of practices develops toward a more critical and dialogic kind of practices. How could this happen? The teachers participated to the same in-service program in which they learned about dialogical thinking but they did not try to act in the successive activities in a concerted way. They did not see the same students. We contend that the social process that enabled the appropriation of the use of form and function of the Digalo tool resembled a relay race. Some of the students participating in the nth session participated also in the (n+1)th session. Also, the tool was present in all activities and enabled a dual stimulation (Engestrom, 2004), that made relevant for the discussants practices and understandings developed in previous activities. Some students were apparently agents of change in practice. Although the teachers felt threatened by the new technology, its appropriation was accomplished "in spite of them".

In this short paper we did not describe the in-service program in which teachers contributed with designers, researchers and educators in the design of activities and in the elaboration of new pedagogies. Therefore, these teachers participated in two activity systems, the in-service program and the classroom discussions. In both activities the Digalo was central. This bilateral consequential transition (King, 1999) enables the evolution of practices at the level of the individual teachers. In addition, the appropriation of technological tools comes from the fact that the teachers became part of a community, in their teachers training development program that supported and enabled them to change their position in the learning process, to 'see' their students' needs, and to identify where they were, made this assimilation process successful. Another, possible reason to this successful integration can be the tool itself – Digalo. The tool afforded to capitalize on familiar face to face practices to develop new forms of productive discussions (Asterhan & Eisenmann, 2009; Schwarz & de Groot, 2007).

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Towards Design-Based Knowledge-Building Practices in Teaching

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Abstract: This paper explores knowledge building in a community identified by Bielaczyc and Collins (2006) as a hotbed community—a community in which knowledge creation has taken on a life of its own. The practices of six elementary schoolteachers are analyzed to inform the development of teachers' knowledge-building practices and to better understand how teachers develop and sustain innovative knowledge-building practices.

Overview

Helping teachers learn and develop as professionals is of great consequence to the teaching profession (Darling-Hammond & Bransford, 2005). To address this challenge, a line of research reported below focuses on a shift from "individual" to "communal" processes (Shulman & Shulman, 2004; Hammerness, Darling-Hammond, Bransford, Berliner, Cochran-Smith, McDonald, et al., 2005). As argued by Darling-Hammond and McLaughlin (1995), conventional ideas of in-service training or knowledge diffusion need to be replaced by opportunities for knowledge sharing; teachers need to be provided with opportunities to share what they know, discuss what they do not understand and relate new concepts and strategies to their own unique teaching contexts. Accordingly, many designs in relation to community-based teaching-learning have been proposed in response to this change of perspective (e.g., see Grossman, Wineburg, & Woolworth, 2001; Hammerness et al, 2005; Palincsar, Magnusson, Marano, Ford, & Brown, 1998).

More recently, however, scholars have further identified the need to transform teacher-learning communities into knowledge-creating or knowledge-building communities (Bielaczyc & Collins, 2006; Chan & van Aalst, 2006; Hargreaves, 1999; Scardamalia, & Bereiter, 1999; Zhang, Hong, Teo, Scardamalia, & Morley, 2008). These communities do not function merely as "learning" communities with the goal of replicating best practice or applying ideas from the educational research community. Instead, a knowledge-building community works to advance knowledge by helping to advance both theory and practice, with the goal of going "beyond best practice." They function more like a research, business, or scientific knowledge-creating organization than traditional teacher communities where the notion of "beyond best practice" is underrepresented, especially in comparison to research communities and knowledge-intensive industries where knowledge building and innovation are expected.

In the present study, we explore the dynamics of a teacher community committed to continually improving their practices so that they are able to advance beyond "best practice." The teachers in this community are engaged in collective knowledge building, in their interactions with each other, as part of a larger professional development community, and in their work with their students. Knowledge building is a social process focused on the production and continual improvement of ideas of value to a community (Scardamalia & Bereiter, 2003), and defined by a set of 12 knowledge-building principles which represent design challenges, ideals, and improvable objects in their own right (see Scardamalia, 2002, for detailed description). For example, the principle of "community knowledge, collective responsibility" emphasizes that contributions to shared, top-level goals of the community be rewarded as much as individual achievements and that community members produce ideas of value to others and share responsibility for the overall community knowledge advances (Scardamalia, 2002). The set of principles enables a theoretically-guided or principle-based design approach to teaching practice (Hong, Scardamalia, Messina, & Teo, 2008; Zhang, Hong, Teo, Scardamalia, & Morley, 2008), as contrasted with conventional classroom work defined by pre-specified procedures, clear scripts and rules, or componential tasks (see, e.g., Dick & Carey, 1990; Gagne, Wagers & Briggs, 1992, Mager, 1975; Merrill, 1983) or any highly-structured teaching activities that represent fixed rather than improvable classroom procedures (Hong & Sullivan, accepted). The purpose of this exploratory study is to uncover the nature and document the process of how these teachers worked together as a community and engaged in sustained knowledge advancement.

Method

Participants were six teachers from the Institute of Child Studies (ICS), University of Toronto. ICS is a laboratory school and it enrolls students from Nursery (Pre-K) to Grade 6, with each classroom having approximately 22 students. Knowledge building pedagogy was first used at ICS in late 1996. There have been quite a few changes of staff over the years, but each of the six teachers has had several years of experience with knowledge building pedagogy. Data were mainly gathered from the teachers' reflective journals (also known as “Calendar of Inquiry”, COI) recorded in a Knowledge Forum database between September, 2002 and April, 2004. Knowledge Forum is a computer-supported knowledge building environment, which provides knowledge building supports both in the creation of ideas and in the ways these ideas are displayed and linked (Scardamalia, 2004). In the present study, Knowledge Forum was employed to provide the teachers an online, public space for collective problem-solving, and a means to their professional development. The teachers used Knowledge Forum to share their teaching reflection with their colleagues by posting their reflective journals (in the form of notes).

In addition, the teachers also met face-to-face for about two hours on a weekly basis to further discuss their problem of understanding, knowledge advances, and technological issues, in relation to their knowledge building practice in class. The teachers’ reflective journals thus not only served as an end for their self-reflection but also as a means for synthesizing their collective, reflective wisdom derived from the meeting. The average number of words produced in each teacher’s journal is 174,808 (SD=29,134.67).

As the main interest of the present study is to understand the nature and process of how these teachers together engage in knowledge-building practice, we intend to propose a theory of these teachers’ collective knowledge building practices. So a qualitative analysis approach based on grounded theory (Strauss & Corbin, 1990) was employed to analyze these journals. Specifically, the three coding stages based on grounded theory (Strauss & Corbin, 1990) were employed: open, axial and selective coding.

Data Analysis

Open Coding

The analytic procedure referred to in grounded theory as “the constant comparative method of analysis” was adopted for open coding (Strauss & Corbin, 1990). The first author was the major coder. Twenty-four codes that emerged from free coding of data were categorized into five major categories, along with their properties and dimensions, as identified in Table 1. In grounded theory, each category represents an observed phenomenon. Properties are attributes or characteristics pertaining to each phenomenon while dimensions are a location of properties along a continuum. For example, phenomena in the “Design” category can be based on the control property (how much control the teacher has of the situation) and where they are on a continuum from a conservative “meeting expectations” to an adventurous chance/emergent dimension.

Table 1: Open coding of the teachers’ collective knowledge-building practices

Categories	Properties	Dimension (Continuum)	
Design (principle-based)	Control	Planned/Expected	Emergent/Chance
	Sequence	Past (design implementation)	Future (re-design)
Problem Identification	Nature	Recurrent	Progressive
	Relevance	Teaching relevant (i.e., pedagogical and curricular)	Less teaching relevant (e.g., technical issues)
	Source	Self-generated	Other-generated
Reflection	Orientation	Practice-oriented	Theory-oriented
	Means	Intra-personal reflection	Group or collective reflection
Theory Evaluation	Relevance	Knowledge building principles oriented	Non knowledge building principles oriented
	Context	Local theory: specific to class context	Universal theory: general to most class context
Deeper Understanding	Source	Personal experience	Vicarious or shared experience
	Means	Trial and error	Reflective
	Object	Practical knowledge	Theoretical knowledge

Axial Coding

To further analyze our data, axial coding is adopted to put the coded data (see Table 1) back together in new ways by making connections between categories. Figure 1 represents the coding scheme used to interpret the data. A major purpose of employing grounded theory is to explore causal relationships, by integrating major phenomena identified from data into a basic causal framework. As suggested in Figure 1, it is posited that the central phenomenon is problemization (Problem); the causal conditions are design related activities (Design); the Intervening Conditions are teachers’ reflective practices (Reflection and Theory Evaluation); and the consequences are teachers’ improved knowledge and gradually more refined experiences (Deeper Understanding).

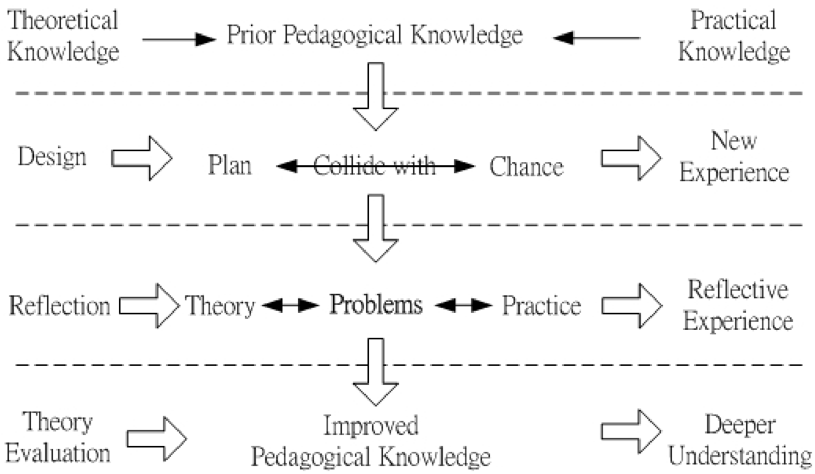

Figure 1. Teachers' collective knowledge-building practices

Selective Coding

Our third-level, selective coding, involved building a story to connect categories. The unfolding story suggests that teachers commonly start their journal writing by posing a problem encountered in class teaching due to the collision between their design and emergent situations. A large portion of their narrative then describes their class teaching experiences related to the problem that emerged, followed by further individual and group reflection on the problems and insights gained. In the following analysis, we further elaborate relationships between problem-reflection, and attempts to characterize the causal relationships and cycles of activity that underlie their design process. Excerpted examples are also included to corroborate the findings.

Central phenomenon.

The central or major phenomenon was identified to be progressive problem-solving surrounding three main kinds of problems: pedagogical, curricular and technical. Problem-solving was progressive, in the sense that teachers continually addressed new problems and/or reconstructed previously addressed problems at continually higher levels rather than allowing the same problem to appear repeatedly. For example, in attempting to help young children develop a stronger sense of community, the Grade 2 teacher tried to look at the same problem in several different ways, while at the same time inviting colleague for collective reflection and problem-solving:

> I am wondering how to get the children to put the information they are learning onto the view. I have encouraged them to think about what we have been doing, discussing and adding to our blackboard chart and to add all this to the Community view [a Knowledge Forum "view" is a collective problem-solving and design space], but they have not been following through on my suggestions. Any ideas? I'm trying to maintain a balance between giving the children some guidance and not making them feel as if I am telling them what to put on the view. On the other hand, I would like the notes to reflect their growing understanding of community.

Causal conditions.

As suggested above, these teachers work with a set of knowledge-building principles, but these principles do not serve as prescriptions, but rather as design parameters. Teachers use these principles flexibly and engage continuously in design, balancing chance circumstances and the constraints within which they work as they open up new possibilities for knowledge building practice and theory. For example, in order to support the knowledge building principle of "idea diversity," the Grade 1 teacher commented:

> This year, I would like to have the children tackle KF in a different way…after sharing their ideas, all captured on paper by the teacher, they will decide what collaborative note they want to post on KF. This way their ideas are more generally heard and the process of knowledge building becomes more transparent...I hope.

Intervening Conditions.

The data suggest that the starting point for progressive problem-solving has more to do with the design challenge the teacher is facing than to efforts directed specifically at implementing a particular theory or practice. For example, one teacher engaged in a 3-year effort to improve his practice, with the principle "community knowledge, collective responsibility" as the stated goal (see Zhang, Scardamalia, Reeve, & Messina, in press). In the process he substantially altered his practices, with corresponding improvement in student outcomes. Throughout there was continual movement between theory and practice, with challenges in implementation resulting in refinements to both practice and principle. The means of reflection (both individual and collective) is related to the context in which the teachers work. They all move between theory and practice to some extent, as the following reflection on a question regarding young kids' metacognitive capacity suggests. The Nursery Grade teacher reflected in her journal:

> One of the MA students in my room was talking to me about assessment and asked can the kids do "self-assessment?". This seems directly related to the questions I've been having about knowledge building at this age. Are the kids conscious enough about the learning process (their own or others') to monitor (assess) as they go?

Consequences.

The data also suggest that teachers innovate by transforming their personal teaching experiences (i.e. more crude experience of initial design, or trial and error, and more refined reflective experience, see Dewey, 1938) into deeper understanding and integrated knowledge of theory and practice. For example, after conducting a three-year, design-based research in his own class, the Grade 4 teacher wrote:

> In analyzing the data from the past 3 years, it seems true (contrary to my original hypothesis), that there has been progress each year in the significant change from pre-test to post-test, significantly more activity each year, and even the portfolio notes themselves seem to suggest that the students have been demonstrating epistemic agency [i.e., a knowledge building principle]. Building from last's years success (a year with students working organically in any study group they were interested in) with less structure, I think this year, I will continue to test the boundaries by consciously trying to not influence the direction of the study. Students will be asked to write Problems of Understanding notes tomorrow. We will look at them on Friday and try to come up with a class mission statement to ensure that the community is working toward the collection of a common understanding made up of various studies. Exciting times ahead!

Discussion

What is unique about knowledge building practices in teaching? How does it differ from other teaching practices? We first consider more common perspectives, for example "teaching as craft" (Bereiter, 2002). Such craft practice is largely guided by one's personal experience (Leinhardt, 1990) and tends to capitalize on specific teaching experiences in order to generate useful rules of thumb for problem-solving. Such practical knowledge can be associated with what Polanyi (1967) described as 'tacit' personal knowledge. Another is replication of best practices, often accomplished by eliminating problems that emerge to cause unexpected difficulties so that the "best practice" can be adopted without variation. Another practice might be termed "theory-to-practice." in which the goal is to capitalize on existing theories for solving problems in relation to teaching practice. However, this is also a problem-elimination approach, to the extent that it emphasizes the general applicability of theory (universality) and overlooks the unique role of practical knowledge in refining theory (cf. Sawyer, 2004).

Knowledge building practice, in contrast, involves a more dynamic and integrated approach in which teachers reflectively move between principle-based pedagogical ideas and practical strategies with the goal of advancing both. It capitalizes both on the strength of design and that of adventurous teaching (Cohen, 1989; Sawyer, 2004), allowing new problems to emerge or recurrent problems to be re-defined and transformed for progressively more advanced problem-solving, with unplanned, new learning designs collaboratively improvised through classroom interaction (Zhang et al., 2008). This represents an important form of teacher professional development aimed at cultivating more reflective and innovative teachers.

In summary, while teaching has been viewed as a craft (Bereiter, 2002) and the idea of education as a progressive science is new to most teachers and to the discipline as a whole (Bereiter, 2002; Cohen, 1989), the teachers in this study engaged continuously in progressive problem solving (Bereiter & Scardamalia, 2003), with practice and theory reciprocally linked, and new designs serving to advance both their practices and student achievement. The current study suggests that it is important to foster a teaching culture with theory-practice interaction through teachers' collective reflective experience (Dewey, 1938), and to make innovation in teaching practice a common knowledge-building experience among teachers.

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CSCL for Teacher Professional Development

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Abstract: Within the last fifteen years, many colleges of the province of Quebec in Canada have been faced with low admission rates in some less popular technical programs. The increased financial burden for these institutions and the enhanced task burden for teachers working with small groups of students threaten the quality of teaching and learning. In order to cope with this situation, computer-mediated collaboration (telecollaboration) was used to provide teachers with the opportunity to work with colleagues from other colleges who teach similar courses. In this short paper, the impacts of telecollaboration on resources diversity and teacher professional development are examined. After four semesters of experimentation, questionnaires and interviews suggest that teachers learned from their colleagues as they shared ideas and acquired pedagogical and technopedagogical knowledge and skills.

Introduction

Positive effects of collaborative and cooperative learning are well documented for students (Abrami, 1996; Johnson and Johnson, 1994). However, the same process is only marginally studied for teachers, especially regarding computer-mediated collaboration. In the province of Quebec (Canada), many college teachers work in remote regions and have only a limited number of students and colleagues. In order to provide more isolated teachers with opportunities to share pedagogical and disciplinary ideas, Quebec's ministry of education implemented a project (the CEGEP network project) creating teams of teachers from different colleges. CSCL is used to foster professional development, and computer-supported telecollaboration is also used among their students.

Context and background

In Quebec, admission rates are diminishing in many technical programs, especially in remote regions (Inchauspé, 2004). Rural youths migrate in numbers to more urban areas (Gauthier, Molgat and Côté, 2001) and information on career opportunities related to less popular programs often fails to reach students. These programs are often important for regional economic development, because they train specialized workers for local enterprises. Maintaining these programs represents an increased financial burden on colleges in remote regions (Inchauspé 2004), and teachers working in these programs face increased workloads. Individuals are often responsible for all courses even though they are not necessarily experts in all subjects. Loneliness and work overloads are a threat for teachers and the lack of diversity of resources (teachers, other students, technical resources, etc.) available for learning may threaten the quality of the student learning experience. As the demographic decline continues, this situation is not expected to improve in the future.

Using telecollaboration to sustain teacher professional development and program vitality

In order to cope with this problematic situation (Inchauspé 2004), CEFRIO (*Centre francophone d'informatisation des organizations* or French-language organizational computerization centre) launched a project in which computer-mediated collaboration (telecollaboration) is used to foster professional development and resource diversity in both informal and formal ways. In the CEGEP network project, telecollaboration was used to pair up teachers working in similar programs in remote colleges to design learning activities for use in jointly run remote classes. In these activities, students were typically encouraged to work in teams even though they were physically separate. The CEGEP network project was designed to encourage teachers to share resources and expertise based on regional specificities. In this first phase of the project, we wanted to test the possibility of improving program vitality, defined as teacher professional development and the diversity of resources available to both teachers and students. The aim of the project is to find ways to help maintain these endangered programs in small colleges while maintaining or improving the programs' vitality.

Even though teachers were free to decide how to collaborate with their students (choice of activities, pedagogical design and class interventions), the researchers and colleges supported the teachers in numerous ways. The colleges have ICT counselors who can help teachers deal with instructional design and effective use of ICT in class. The ICT counselors were trained by the researchers, and the ICT teams gave guidance to the teacher teams. At each semester, meetings were held to train teachers and ICT counselors on the design of computer-supported collaborative learning and to reflect on best practices with teachers, administrators, researchers and counselors.

Literature review

Models of teacher professional development

In this research, program vitality is intrinsically linked to opportunities for teacher professional development. Professional development has traditionally been considered as a linear process. Teachers would participate in one-off workshops presenting new and more efficient ways of teaching. Afterwards, they would eventually incorporate these new strategies into their own teaching practices (Butler et al., 2004; Clarke and Hollingsworth, 2002). In these models, teachers act as technicians who individually apply external knowledge developed by researchers (Butler at al., 2004) and only formal training is recognized as a source of change in practices (Clarke and Hollingsworth, 2002).

Other researchers argue that professional development is similar to any other learning process and therefore use recent learning theories such as socio-constructivism (Knight, 2002) or self-regulation models (Butler et al., 2004) in their work. For them, professional development is a reflective and continuing process in which teachers construct their own instructional knowledge (Butler et al., 2004; Clarke and Hollingsworth, 2002). Informal opportunities to learn from colleagues or to reflect on teaching practices are examined by these researchers as well as formal training workshops (Uwamariya and Mukamurera, 2005). Communities of practice can also be part of the professional development process, providing space for reflection and common goals to meet (Triggs and John, 2004; Hamel, 2003). For these authors, professional development is not conceptualized as a top-down transmission of knowledge in this study. It is an individual and collective learning process fuelled by diverse opportunities for reflection and change, with changes in teaching practices and attitudes serving as indicators of learning (Clarke and Hollingsworth, 2002; Gusket and Sparks, 2002).

Characteristics of the change environment

In this study, even though different sessions of formal training took place, the project consisted mostly of the implementation of an environment promoting discussion, collaboration in the implementation of new teaching practices and reflection on these practices and their results. In Clarke and Hollingsworth's interconnected model of professional growth (2002), the change environment and the external domains are particularly important for changing teachers' beliefs and practices.

External learning opportunities can be formal or informal. Discussions with colleagues, instructional resources, counselor support (Triggs and John, 2004; Clarke and Hollingsworth, 2002; Clement and Vandenberghe, 2000) and formal training (Gusket and Sparks, 2002) can all fuel professional development. Nevertheless, the atmosphere in which the teachers work is crucial in order for reflection and change to happen. Departments with institutional policies and practices geared at professional development (Gusket and Sparks, 2002; Clark and Hollingsworth, 2002) or opportunities to experiment without being judged by colleagues or administrators provide such an atmosphere (Triggs and John, 2004). Can computer-mediated collaboration or telecollaboration create such an environment for teachers?

Research question

This short paper addresses the following question: To what extent can telecollaboration increase the vitality of technical programs with low admission rates? Two major dimensions of vitality were examined: resource diversity and professional development.

Methodology

Context

The CEGEP network project was implemented during the 2006 winter semester. To allow teachers and students to communicate together, three major tools were chosen before the project started. The first one is a videoconferencing program called Via (similar to Adobe Connect or Elluminate) which offers different collaborative tools such as a presentation area, an interactive white board, a chat system and document and application sharing. Teachers and students also used another videoconferencing tool (telepresence window) and a learning management system (DECclic) to communicate and share documents. During the first four semesters of the *CEGEP network project*, more than 30 teachers, 200 students, 25 administrators and 11 ICT counselors from 11 colleges in the province of Quebec participated. Data collection started during the second semester of implementation (fall 2006) and ended in December 2007.

Procedure

This study employs a design-based methodology with mixed methods. Each semester of the project represented an iteration, and data were collected each semester through general meetings with the participating teachers, ICT counselors and administrators to present successful and unsuccessful cases and reflect on best practices. While lessons learned on the design of computer-supported collaborative activities are not the focus of this paper, they were communicated to all participants at each iteration. The implementation of computer-supported learning activities for students was the focus of teacher collaboration, and data were collected from students in various ways, but the focus of the first phase of this study was the teachers. While the teachers were learning to implement successful learning activities, in the second phase of the project (ending in June 2009), the focus gradually shifted towards the students.

The researchers visited the colleges many times between 2006 and 2007 and witnessed discussions and changes in teacher practices through participant observation. Questionnaires on computer literacy, frequency of ICT use, professional development workshops and barriers to telecollaboration were distributed twice in 2007. In the middle of the winter semester, 53 teachers answered the questionnaire while only 24 did at the end of the fall semester. The results were analyzed using SPSS. For qualitative information, individual interviews were held with nine participant teachers, and notes were taken during four meetings of the coordination committee. All interviews were transcribed and coded using a code book developed by the research team. Atlas.ti was used to perform analyses on the transcripts and calculate code frequencies.

Results

Types of collaborative activities

Collaboration between teachers increased as they became more familiar with the technological tools. The teachers mostly used Via to plan learning activities because of its elaborate tools for collaborative work (for example the ability to comment documents and share applications was popular among teachers). Some of them also used SKYPE to communicate outside normal working hours or when they needed help from ICT counselors in another college. Statistics on videoconferencing use (Via) obtained through the software database show that the number of work sessions between teachers increased between 2006 and 2007 while training decreased (see figure 1). Indeed, at the end of 2007, teachers sometimes met every week to plan for future learning activities. These activities were also more numerous at the end of the experimentation period.

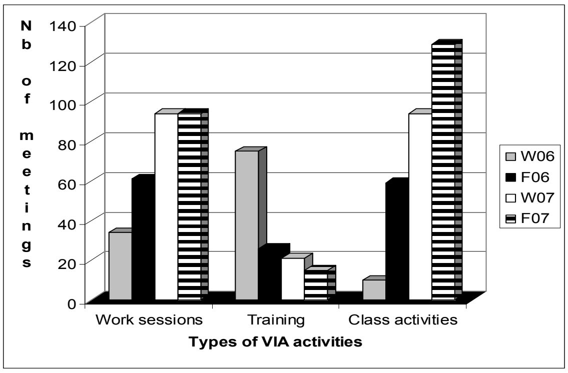

Figure 1: Distribution of the types of activities performed using VIA

Changes in teaching practices

Teaching practices changed during the four trial semesters, which is a good indicator of professional development (Clack and Hollingsworth 2002). At first, lecture was often used by teams of teachers who combined all their students into a single virtual group. Teachers took turns lecturing in their own classroom while the students not physically present followed the lesson through a videoconferencing system. When teamwork was organized, the learning activities were short, lasting for only one or two classes. In contrast, in the fourth trial semester, the learning activities were more diversified. Some teachers asked students from different colleges to work in teams on a project for a few weeks or the whole semester. The teachers realized that the students lost interest quickly while listening to lectures in front of a computer, so they largely abandoned this particular teaching method in favor of more engaging ones. In brief, the researchers observed positive development in instructional design.

Effects on resource diversity

All nine teachers reported at least once in interviews that they benefited from the expertise of one or more colleagues in their discipline during the CEGEP network project experiment. Learning from a colleague who is not specialized in the same domain as the other teachers in the team is a positive impact of telecollaboration, according to the teachers. Sometimes, each teacher on the team taught lessons related to their own area of specialization and they were no longer required to lecture on notions topics outside of their expertise. This can eventually reduce individual workloads. Experienced teachers can also provide help on instructional design to those who have just started teaching. Thus, subject-matter and pedagogical resources are shared from one college to another.

Six out of seven teachers emphasized that their access to instructional and technological materials increased when they participated in the CEGEP network project. They shared their own teaching materials with teammates or used some of it to build telecollaborative learning activities. Telecollaboration tools are other resources that can benefit teachers from participating college in the future. Workshops and demonstrations were held in some colleges to show the potential of telecollaboration to all the members of the institution. Consequently, teachers benefited from more human and material resources with the implementation of the CEGEP network project.

Professional development

All teachers referred to professional development in the interviews (see table 1).

Table 1: Frequency of references to professional development in the interviews

	No. of teachers who mentioned it		Total # of references
	Individual interviews (/9)	Coordination committee (/4)	
Professional development	**9**	**3**	**149**
Discussions and sharing	9	2	70
Knowledge and skills acquisition	6	3	63
Pedagogical	5	1	33
Technological pedagogical	3	2	19
Technological	1	1	2
Content	1	0	2
Others	2	2	7
Feeling less isolated	4	0	16

"Discussions and sharing" was the category most unanimously and frequently mentioned in the corpus. The teachers all mentioned discussing different aspects of their work with colleagues. For example, they enjoyed learning about what was going on in other colleges. They also emphasized that they benefited from the expertise of one or more colleagues in their discipline during the CEGEP network project. Five out of seven teachers emphasized pedagogical discussions as a positive consequence of the project. Even though the teachers did not often precisely identify what kind of collaboration took place during the project, they all stated that telecollaboration made them talk and think about their own teaching practices.

The CEGEP network project provided opportunities for increased knowledge and skills, according to six teachers out of nine. Moreover, questionnaire results indicate that proficiency with Via increased significantly between the beginning and the end of 2007 ($df = 1$; $f=11,999$; $p=0,001$). It does not seem that other purely technological skills increased for participant teachers, but the small sample reduces the possibility for statistical analysis and the participants were already highly computer literate. Nevertheless, the teachers learned more than just using new technology.

In interviews, teachers identified two important skills that they acquired throughout the project. The first skill is the effective use of telecollaboration in the classroom. No model of telecollaboration between students of different colleges was available in theory. The teachers therefore collectively constructed knowledge from reflections on their best and worst practices. The second important skill was in instructional design. Some teachers realized that they faced similar challenges in both distance and traditional classes. They believe that they can apply what they learned in the CEGEP network project to improve their teaching practices and better motivate students in class. Telecollaboration with colleagues helped teachers reflect on teaching beyond the use of technology to foster collaboration between students.

Discussion

Results suggest that pedagogical resources and expertise increased during the four semesters of experimentation, providing opportunities for professional development (Triggs and John, 2004; Clement and Vandenberghe, 2000). The teachers also reported that they acquired technopedagogical and pedagogical knowledge, while the researchers witnessed changes in their practices throughout the experimentation. The teachers were able to use telecollaboration as an opportunity to construct their own knowledge on teaching and learning.

The quality of telecollaboration varied across teacher teams, however. Teachers often had to considerably modify their course outline because paired programs and courses were sometimes significantly different. When teaching styles differed too much within a team, disagreements over the design of telecollaborative learning activities made the learning experience less rewarding. Moreover, in some colleges, participating teachers had to quit their jobs for reasons of illness, retirement or lack of student registration. Collaboration could not continue with teachers in only one college in those teams.

As reported in other studies, some key elements for successful telecollaboration between teachers were identified: technological factors, teacher commitment and interest (related to time and financial allocations). But the quality of the collaboration experience also depended on socio-affective factors (professional climate and confidence), pedagogical factors (compatibility of teaching approaches and objectives), administrative factors and the teachers' technopedagogical competencies (or TPK in Mishra and Koestler's TPACK model). As suggested in the Butler et al. self-regulation model (2004), the most successful teacher teams devoted time to reflect on the activities and measure and discuss the learning outcomes.

Conclusion

After only four semesters of experimentation, telecollaboration experienced through the CEGEP network project seems promising as a means to foster teacher professional development. In this project, computer-mediated collaboration enabled teachers to share expertise, ideas and materials in programs with low admission rates. The degree of success varied across teacher teams, however, and different barriers to telecollaboration were identified by researchers and participants. Moreover, the impacts of telecollaboration on students need to be studied more closely in order to achieve program vitality. The small samples of participating teachers and students are another limit of this study because statistical analyses are difficult to perform with such low numbers. Nevertheless, teacher telecollaboration continues with the CEGEP network project. More precise measures of teacher and student learning will help us to understand how CSCL can foster learning at the workplace and at school in future research.

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Three years of teaching resource sharing by primary school teachers trainees on a CSCW platform

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Abstract: In this paper, we propose a unit of analysis to study traces in CSCW, the higher level shared folder (*hlsf*), which we define. We use it here to analyze how teaching resource pooling and sharing has been operated by the teacher trainees within the IUFM de La Réunion for three years. We verify that this sharing was effective, we see how it was structured and we study its evolution during those three years.

Introduction

The Reunion Island teacher training school (IUFM) provides courses to trainees who wish to become fully qualified teachers. In this paper, we will focus on primary teachers (PEs, i.e. professeurs des écoles). The training of primary teachers alternates according to two periods throughout the year:

- a period in the IUFM when they follow the courses ;
- a period of training when they are in charge of a class and must teach pupils in a primary school.

In 2004-2005, trainers and PEs asked for a groupware (Simon, 06). We have presented in (Simon & al, 08) the reasons of the trainers for this demand. For the PEs, the groupware should allow them to pool and share teaching material during the training period and thus reduce their workload. For them, sharing teaching material consisted in putting on line and at the disposal of the other members various types of production: lesson plans, resources which could be used by pupils during class… In September 2005, BSCW (Basic Support for Cooperative Work) (Bentley & al, 97) was chosen as CSCW platform because it's free for an educational use and it offers a sufficiently large degree of freedom to allow easy cooperation between the various users. During three years, from September 2005 to July 2008, the different cohorts of trainees, but the same trainers, who work each year at the IUFM, have generated hundred of thousands recordings on this platform. Those recordings went from the simple consultation to the creation and the maintenance of complex shared workspaces.

We will analyze here more particularly those generated only by the PEs. *We will see if there really was resource sharing when the PEs were not supervised by a trainer and how it was organized. Another element that we want to check is to see up to what point most of the PEs were involved in the process. Finally, we want to know if there is an evolution in the way they are working.* But, for that, we have to use a unit of analysis smaller than the total activity of the CSCW platform which is usually employed in research. The reason is that there is a lot of activities that were being operated on it at the same time and we want to focus only on resource sharing. First, in the methodology, we will introduce the unit of analysis we will use, second, we will expose the results we obtained and, finally, we will conclude with the limits of this work and the openings which it allows.

Methodology

Analysis of the traces on BSCW

The unit of research analysis concerning the CSCW on BSCW is often the total activity of the platform. This activity is analyzed through the various events which occurred: creation, modification, reading, removal of files, documents, threaded discussions… out of which statistics are processed. (Appelt & al, 01) post the percentages for the various types of events: creation of folders, documents, discussion, reading ... (Daradoumis & al, 03) gathers the events in 4 categories: creation, modification, reading and removal. (Gonzalès & al, 05) exploit the time of use, the number and the type of events: reading, creation of documents…It is rare for a treatment of units smaller than the total activity of the platform to be made. Nevertheless, a CSCW platform allows various types of activities to operate at the same time. Between an “on-line course with a teacher” use or a “resource sharing between peers” use such as the one considered here, neither the same events, nor the same organizations will be obtained. In the same way, it is rare for a distinction to be made between the constituted groups (e.g. the teacher with his trainees, the peers chosen between them…) in the publications. The categories suggested, when there is any, are very vast and are defined by the researchers themselves. For instance, (Appelt & al, 01) distinguish between neophytes and confirmed users, (Gonzalès & al, 05) distinguish between the training centers: Poland, Romania, Italy and Spain. So since the “type of activity” and “form of the groups” parameters are not taken into account, it is difficult to interpret the obtained results. Thus when (Daradoumis & al, 03) check if all the users take part to CSCW, one can wonder whether the obtained results are related, or not, to the activities suggested and the constitutions of the groups. For our part, if we use a metaphor, we don't want to simply count the number of footprints left, we want to know where they go, what path they follow and to whom they belong.

Unit of analysis: the higher level shared folder (*hlsf*)

This is why what distinguishes our research from the preceding ones is the unit of analysis we have chosen. To define such a unit, we refer to one of the central ideas of the Activity Theory (Engeström, 87): the form of the activity depends of its goal. So, the unit we use, here, is *the higher level shared folder* (shortened to *hlsf). The* postulate is: *the hlsf reflects the activity of the members of a group working together to solve a problem.*

We defined the *higher level shared folder* in the following way (Simon & al, 08) a *hlsf* is:

- a shared folder not belonging to any folder, in other words a shared folder which is at the root and which is thus contained in no other folder,
- or a shared folder belonging to a folder which is, itself, not a shared folder and which is at the root. A user can sometimes gather in the same folder (not shared) the folders which he/she shares with several different groups.

Defined in this way, it allows us to make distinctions between groups but also between the objectives (Dillenbourg & al, 96) and thus to analyze the activity on the platform according to those two parameters.

In BSCW, information is organized hierarchically in folders and sub-folders and takes the form of various documents (texts, tables, URL…) which are created, read, modified, restructured… The *hlsf* is the widest response to the problem while one of its sub-folders, for its part, brings a response to a part of this problem. The problems are not the same, so the higher level shared folders will not be identical either.

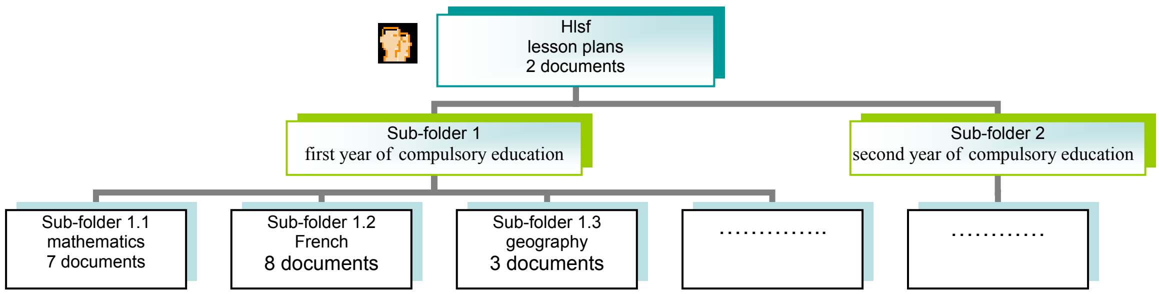

Figure 1. An example of *hlsf*. The heads symbolize the group of members associated with the *hlsf*. Each folder can itself contain sub-folders and documents

For a technical point of view, to analyze the data, we have translated the plain text file where BSCW stores all its data in tables which we worked with a relational DBMS (Gonzalès & al, 05). In this plain text file, the user category of the PEs was distinguished from the others by the logins beginning by "PE2" (e.g.: PE2smith). That has made it possible to locate the *hlsf* only shared by them (without trainer). In this way, one notes that it is easy to automate the treatments.

Results

In what follows, we analyze the *hlsfs* created by the different PEs of the IUFM for pooling and sharing their teaching resources during three years. *It's important to note that, each year, this is a new cohort of PEs which comes to the IUFM to be trained and that, in the hlsfs we study here, there is no participation of trainers, the groups are constituted only of PEs.* Moreover, each year, all the traces left by the previous cohort are deleted.

Table 1: Number of PE and number of *hlsf* they have created.

	2005-2006	2006-2007	2007-2008	over 3 years
Number of *hlsf*	289	189	89	567
Number of PE (trainees)	343	277	217	837
Number of hlsfs for one PE	***0,84***	***0,68***	***0,41***	***0,68***

As we can note in Table 1, there are fewer and fewer trainees each year because the region needs fewer and fewer teachers. That's one of the reasons why there are also fewer and fewer *hlsfs* but it's not the only one. As we can see on the fourth line of this table the number of *hlsfs* for one PE is going down as well. We will explain that in the second section. In a first time, we will see if the results concerning 2005-2006 published in (Simon & al, 2008) are still valid for the following years: participation, roles of the members... We will be interested in the members of the group associated with each *hlsf* and we will see up to what point there is an effective participation of each one and of which type this participation is. In a second time, we will observe the evolution of the *hlsfs* structure and the evolution of the activity inside those *hlsfs* during the three years.

Confirmation of the results of 2005-2006

Each *hlsf* is thus shared by a group of PE which upload, modify or consult resources which they use to prepare their lesson. The question is posed of the participation within the *hlsf* of each member of these groups. In (Simon & al, 08) we have studied the *hlsfs* produced by the PE between September 2005 and August 2006. Most of the results remain true.

Since 2006-2007 almost all the PE (98%) belong to one *hlsf* at least

Table 2 distributes the PE according to the number of *hlsf* in which they take part. Over the three years, only 76 PEs, on the 837 PEs enrolled at the IUFM, didn't participate to a *hlsf*. Near 91% took part in one *hlsf* at least and since 2006-2007 almost all the PE (98%) do it. More than 30% of them took part in more than 10 *hlsfs*. As one will see more precisely below, one thus notes that the installation of a CSCW platform meets a real need.

Table 2: Participation of the PEs to one or more *hlsf.*

	2005-2006		2006-2007		2007-2008		sur les 3ans	
Number of *hlsf*	Nb of PE members	%	Nb of PE members	%	Nb of PE members	%	Nb of PE members	%
0	70	20,41%	3	1,08%	3	1,38%	76	9,08%
>=1 et <10	224	65,31%	111	40,07%	163	75,11%	498	59,50%
>=10	49	14,28%	163	58,84%	51	23,50%	263	31,42%
TOTAL	343	100,00%	277	100,00%	217	100,00%	837	100,00%

But they use it differently

To analyze the reality of this participation, we focused on the actions carried out in these *hlsfs* by the PEs, distinguishing between creation of a *hlsf* , creation of sub-folder in this *hlsf*, deposit of document in this *hlsf*, and simple reading. These actions are not the only ones but they are the basic actions impossible to circumvent.

Table 3: Numbers and percentages of PE according to various types of actions carried out.

	2005-2006		2006-2007		2007-2008		Over 3 years	
Roles	Nb of PE	%	Nb of PE	%	Nb of PE	%	Nb of PE	%
Leader : creator of one *hlsf* at least	107	31,20%	114	41,61%	58	26,73%	279	33,33%
moderator : creator of one folder at least in a *hlsf*	119	34,69%	144	51,99%	59	27,19%	322	38,47%
producer : creator of one document at least in a *hlsf*	150	43,73%	158	57,04%	111	51,15%	419	50,06%
reader of one document at least	269	78,43%	256	92,42%	185	85,25%	710	84,83%
Inactive	4	1,16%	18	6,50%	29	13,36%	51	6,09%
member of one *hlsf* at least	*273*	*79,59%*	*274*	98,92%	*214*	98,62%	*761*	90,92%
total number of PE	343	100,00%	277	100,00%	217	100,00%	837	100,00%

Table 3 has to be read as follows: when it's written that "x people have done….", it means "x *different* people". For instance, in 2005-2006, 150 *different* PEs are producers.

One notes the existence of "leaders" (33,33% of the PEs who have created the *hlsf*), and the existence of "moderators" (38,47% who have created folders). So, as we can see, leaders and moderators do not constitute a small minority of decision makers. Anyway, the terms leader and moderator should be used with some caution. Indeed, it is not because a user creates a *hlsf* or a subfolder that he launched the group. It can be imagined that the group would be established at the initiative of another person who has proposed to create a *hlsf* and that the tasks have been distributed. We have studied the number of *hlsf* created on average by each leader, this one has decreased (from 2.70 in 2005-2006 to 1.53 in 2007-2008). At the opposite, the number of folders and sub-folders created on average by each moderator increases (from 1.55 to 5.32). This means that the organization of the *hlsf* is changing as we will see in the second part.

About 50% of the PEs were "producers" because they have created at least one document. The production is relatively constant for the two last years: a producer put on average about 6,5 documents on the platform in the *hlsf*. 84,83% of the PEs have consulted at least one document in a *hlsf*. Each year, one "reader" has consulted on average 20 documents. The number of "inactive" is the difference between the number of members and the number of readers. On average, over the three years, 6,09% of the PEs were inactive. It can be assumed that these PEs were invited to participate in a *hlsf* by their colleagues but they were not really interested in it.

So, one notes through this table that the request of the PEs to pool and share resources was well founded because one PE out of three has created at least one *hlsf* or one subfolder, one out of two has produced at least one document and more than eight out of ten have read at least one document. In this way, when recalling the issue of the effectiveness of the members' participation, the latter can be said to be genuine. However, one notes an imbalance in the roles adopted by the PEs : if 84,83% of the members are "readers" and thus benefit from the resources on the platform, only 50,06% are "producers" who took part in their installation. In the investigation (Simon, 06), PEs have been asked what the rules making resource sharing function could be. The one generally stated indicated that "one could receive only if one has given". Obviously, this rule was not complied with here and one can wonder how a system where near 35% of people take without giving would evolve if it were to be prolonged beyond one year.

Analysis of the organization and the activity of the *hlsf* over 3 years

It's possible to refer to Figure 1 which depicts a *hlsf* to read Table 4. One can see a lower number of *hlsfs* due to the decreasing number of PEs but not only as evidenced by the ratio number of *hlsfs* for one PE of Table 1. Another reason is that the *hlsfs* were organized differently as we will see. One notes first, in Table 4, that the number of members by *hlsf* is rising. It's the same for the number of subfolders and, therefore, the depth of the *hlsfs* is also increasing. The explanation for these two latter increases is, most likely, the steady increase of the number of documents put in the *hlsfs*. More members and more documents naturally bring more readings. To understand this phenomenon more deeply, our colleague (Gerard, 09) began to create the social network of each *hlsf*. We noticed, then, that many of them were with *one* producer only (remember that a producer is a member who deposits one document at least in the *hslf*). So we analysed the *hlsfs* according to the number of producers who work in it.

Table 4: Organization and activity of the *hlsf* .

	2005-2006	2006-2007	2007-2008	over 3 years
Number *of hlsfs*	289	189	89	567
Number of PEs	343	277	217	837
Average number of members for one *hlsf*	8,3	15,45	16,67	12,00
Average number of documents for one *hlsf*	5,26	5,75	7,52	5,78
Average number of readings for one *hlsf*	25,51	28,53	47,06	30,62
Average number of subfolders for one *hlsf*	0,64	2,11	3,53	1,88
Percentage of *hlsfs* with one level at least of subfolder	16,28%	31,75%	37,08%	24,70%

Table 5: Number of *hlsf* according to the number of producers who work in it .

	2005-2006		2006-2007		2007-2008		total	
	nb hslf	%	nb hslf	%	nb hslf	%	nb hslf	%
0 producer	48	16,61%	25	13,23%	11	12,36%	84	14,81%
1 producer	198	68,51%	108	57,14%	21	23,60%	327	57,67%
2 producers and more	43	14,88%	56	29,63%	57	64,04%	156	27,52%
total	289	100,00%	189	100,00%	89	100,00%	567	100,00%

As one can see in the Table 5, the evolution is the same than the one pointed out previously: the number of *hlsfs* with two or more producers is growing up each year, from 15% to 64%.

Thus we see that there are fewer hlsfs but they are more complete, better structured and more active. It seems that, implicitly, PEs follow the rule laid down by their colleagues (Simon, 06): there should be a sufficient number of members and documents for pooling and sharing properly.

Conclusion

Firstly, *considering the results, the analysis seems to show that resource sharing works*. Nearly 90% of the teacher trainees of the IUFM freely decided to be a member of a *hlsf* and among them almost all used the resources. Thus, one can make the assumption that individuals use a tool when they see the profit which they can draw from it. But we have to be careful because only 50% of the members have put some documents on the platform. Moreover this assessment has to be moderated in another way. Behind the idea of resource sharing, there is also the idea of improvement of the resources. In the investigation (Simon, 06), the trainees claimed that they wanted a return on the resources that they had deposited after they had been used. This return under BSCW can be done in various forms: adding a note to the document, modifying the latter… It appears, after analysis of this type of events, that it occurred rarely. We are thus more in cooperation than in collaboration (Dillenbourg & al, 96). One can note also that the organization of the *hlsf* is evolving: *the hlsf are fewer, but they are more complete, better structured, and more active.* What we are going to do now is to categorize the *hlsf*s in, at least, two categories (fewer or more than two producers) and study them separately because we believe that they don't pursue exactly the same objective.

Secondly, considering the method used in this research, it appears that the unit of analysis suggested, the higher level shared folder, *hlsf*, enables to produce some results. The activities on a CSCW platform are not different from those in real life and obey the same logic: a group of individuals link their efforts to solve a problem. *It is necessary to distinguish the activities according to the objectives and according to the groups which perform them because the form that the activity takes (number of participants, type of organization,…) depends on the goal, the problem to be solved (Engeström, 87).* Within the framework of the CSCW, when taking as unit of analysis the total activity of the platform, this particular parameter which is the problem to be solved is lost. Indeed, it is rare for a platform to be dedicated only to one type of activity. Consequently, analyzing the total activity of the platform amounts to pooling various things in the same activity. *This is why we think that the hlsf is a relevant unit of analysis because it makes it possible to distinguish between the types of activity and leads to more precise results.* For instance, in (Simon & al, 08), we have studied *all the hlsfs.* They were separated in two classes: those where there is a trainer and those where the trainer is missing (like here). It is noted there that the produced *hlsfs* do not adopt the same form in both cases.

The analysis of the *hlsf* is a method which comes under the field of trace analysis, and the limits of the latter start to be known. It is often reproached with remaining superficial and in general it is proposed to be supplemented by others in order to go more in-depth (e.g. mixed method (Martinez & al, 06)). This is why the tendencies raised here and the suggested interpretations would require confirmation by other processes: directed investigations, interviews... For the moment, we work on the social networks analysis of the groups associated with the *hslfs* (Gerard, 09). We have also handed a questionnaire to the PEs of the previous years to understand how the *hslf* have been negotiated among them (Stahl, 03).

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Exploring the Process of Convergent Adaptation in Technology-Based Science Curriculum Construction

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Abstract: As a core complex systems process, understanding the dynamics of individual or group adaptation can provide valuable information for constructing professional development strategies that can increase chances of instructional success. This paper reports on an exploratory study that identifies indicators of convergent vs. non-convergent adaptation between two cases of teachers working together on a technology-based curriculum construction activity and explores the relationship between group characteristics and adaptation processes. We have used the complex systems concept of adaptation as a lens for understanding how and why some teachers are better able to adapt to the educational program requirements. The results show that processes of convergence and non-convergence influenced adaptive outcomes, and that the more similar the teaching characteristic index (TCI) number was between group members, the more likely it was that group dynamics would result in convergent adaptive outcomes.

Introduction

The recent focus on using complex systems approaches in educational research has spawned a number of programs, models and frameworks both for understanding how students learn about complex scientific topics (Hmelo, Holton, & Kolodner, 2000; Jacobson & Wilensky, 2006; Yoon, 2008a) and for understanding the complexities inherent in educational systems for the purposes of professional development and educational reform (Fullan, 1993; Yoon & Klopfer, 2006). In this study, we follow on the latter line of research in using a complexity lens to investigate and document teachers' social adaptive processes that help or hinder curriculum construction in the context of a technology-based high school science project. We introduce the concepts of convergent and non-convergent adaptation to assess and predict the outcomes of individual and group dynamics, collaborative products, and success of classroom implementation. As a core complex systems process, understanding the dynamics of individual or group adaptation can provide valuable information for constructing professional development strategies that can increase chances of instructional success. Reiser et al. (2000) for example, describe a study in which achieving mutual adaptation is the goal that drives the use of *work circles* for curriculum construction that consists of teachers and university researchers. They document constraints experienced by the group due to differing perceived work circle purposes. Whereas the researchers in the group were interested in understanding the process by which teachers came to produce the end product, teachers were less interested in articulating rationales and resolving or discussing how differences got resolved. Despite such challenges, the authors state that the team succeeded in creating a coherent curriculum. It appears then that adaptation did occur. However, missing from the discussion is an analysis of mechanisms that propelled the group to this state. Our study extends this work by investigating how processes of convergence and non-convergence can lead to more or less adaptive outcomes. As described in more detail below, convergence as a core collaborative mechanism has been addressed in processes that fuel conceptual change (Roschelle, 1992), knowledge-building (Scardamalia, 2002), and interactional construction of knowledge (Greeno et al., 1998). As we will demonstrate, convergent processes work well with a complex systems lens due to their implicit relational nature. This paper reports on an exploratory study that identifies indicators of convergent vs. non-convergent adaptation between two cases of teachers working together on a technology-based curriculum construction activity and explores the relationship between group characteristics and adaptation processes.

Theoretical Frameworks

Complex systems approaches have been used in the biological sciences since the 1940s when von Bertalanffy (1968) first introduced the study of *Systems Theory*. The utility and ubiquity of this seminal theory has since proven to be enormous as many more knowledge domains have used complex systems concepts to investigate how real world phenomena operate and exist as self-organized coherent structures. For example, this theory has been used to understand behavior in non-linear thermodynamic systems (Prigogine & Stengers, 1984), the evolution of cooperation in social systems (Axelrod, 1984; 2006), synchronization in natural systems (Strogatz, 2003), and the dynamics in cognitive developmental systems (Thelen & Smith, 1994).

Despite variation in physical components or agents, complex systems can generally be defined as existing when any given number of interconnected elements, parts or individuals, communicate in non-linear ways. The patterns of interactions form a collective network of relationships that exhibit emergent properties that are not observable at subsystem levels. When perturbations occur, the network self-organizes often in unpredictable ways where new properties can emerge. In other words, the behavior of the system cannot be accurately determined by simply observing the behavior of the parts. The manner in which complex systems communicate, respond to perturbations and self-organize is understood by studying the dynamical processes through which they evolve over time. Acquiring information from their environment through feedback, complex systems identify regularities in that information and use this to modify behavior in the real world (Gell-Mann, 1994). In this way, they are said to be adaptive. The central interest in our study is investigating this process of adaptation.

Complex Systems in Education

In education, there have been two consistent lines of complex systems research. The first and more common in the learning sciences are studies that investigate how students learn complex scientific topics (Chi, 2005; Hmelo et al., 2007; Jacobson, 2001; Wilensky & Reisman, 2006; Yoon, 2008a; Yoon, 2008b). Results have shown that students typically have difficulties in understanding the complex nature of scientific and social phenomena due to inabilities to grasp core complex systems processes such as decentralization (Resnick, 1996), emergence (Penner, 2000), and complex causality (Grotzer, 2005). In order to assist student learning, computational modeling tools and corresponding curricula such as *StarLogo, NetLogo, Connected Chemistry, Model-It,* and handheld *Participatory Simulations* (Colella et al., 2001; Klopfer et al., 2005; Resnick, 1994; Soloway & Pryor, 1997; Stieff & Wilensky, 2003; Wilensky & Reisman, 2006) have been constructed primarily by learning sciences researchers to visualize the multiple levels, processes and patterns of interacting agents and events.

The second line of research investigates the complexity of implementing educational change. In his *Change Forces* series focused on educational reform, Fullan (1993; 1999; 2003) uses complex systems theory as an organizing framework to reveal core concepts such as non-linearity, unpredictability and multi-level agency that are important issues to contend with in real-world educational systems. Elmore (1996) writes about the difficulties experienced by nested clusters of innovation when trying to move from local to global contexts. He states that failures, historically, in generating successful large-scale reforms can be attributed to an “absence of practical theory that takes account of the institutional complexities that operate on changes in practice” (p. 21). Coburn (2003) reinforces the idea that educational reform and improvement are matters of complexity. She further contends that better research designs must be utilized to capture a more complex vision. Within the CSCL community, an influential body of research has sought to document impacts by educational and information technology programs on educational reform efforts (Dede et al., 2005; Fishman, 2004; Fishman & Pinkard, 2001). One common recommendation for reform strategies amongst these programs is to recognize and leverage the multiple variables and curricular goals of system constituents (Dede & Honan, 2005). Elsewhere we write about a professional development program for implementing one of the above computational modeling tools in a small urban school district. Using a complex systems lens for program construction and evaluation in which the variable of adaptation figured prominently, charting the changes in professional development activities such as workshop foci, facilitation structures, partnership roles and curriculum shifts assisted in coordinating and prioritizing needs as well as revealing important gaps in our professional development programming (Yoon & Klopfer, 2006). In biology, adaptation refers to the notion that organisms become suited to their habitats. It was one of the main concepts enabling Darwin to construct the theory of evolution. The theory can be briefly summed up in the following way. As environmental conditions change, pressures on populations to survive also change. Through the mechanism of inheritance, natural selection, which is the random emergence of new adaptive characteristics, dictates whether organisms survive or become extinct. Varela (1999) extends the idea of biological adaptation to human and social systems. He argues that humans always operate in some kind of immediacy in a given situation and contends that environments and identities are historically constituted. In other words, our ability to function organizes around recurrent patterns of embodied experience as we make transitions from one environment to the next. In cases where human experience cannot cope with a specific environment, we must carefully examine the parameters around which such a breakdown occurs in order to seek better strategies.

Processes of Convergence

What might the parameters that more or less affect adaptive outcomes look like? We found a number of interrelated processes in the learning sciences literature. Greeno et al. (1998) discuss a set of attunement variables that indicate well-coordinated patterns of participation in interactive systems of activity where the group and its actions become the unit of analysis. Indicators of mutual construction of meaning include responses of acceptance, objections, affirmations, and repairing of interpretations. They also discuss from a systems perspective observing trajectories of discursive participation such as turn-taking patterns that can reveal the status of individuals in the group. Thus, one might perceive the dynamics in a group that does not exhibit responses of acceptance, objections etc., as not coordinating well and where convergence on shared meaning may be difficult to achieve. Where trajectories of turn-taking reveal hierarchical rather than decentralized patterns of communication, the differential status of group members may influence types of individual participation. In his seminal work on convergent conceptual change, Roschelle (1992) likewise reveals through patterns of conversational turn-taking, in addition to the content of those turns, that convergent conceptual change is achieved incrementally, interactively and socially through participation in joint activity. The content of turns is key here in that jointly constructed metaphors and progressively higher standards of evidence are necessary conditions for conceptual change to occur. In situations where metaphors are not jointly constructed and where the use of progressively higher standards of evidence does not occur, this might lead to non-convergent adaptation.

Another important set of processes discussed in the CSCL literature deal with the difference between collaborative and cooperative learning (Dillenbourg & Schneider, 1995; O'Donnell & O'Kelly, 1994). Dillenbourg and Schneider (1995) make a distinction between cooperative and collaborative learning in that cooperative learning is "… a protocol in which the task is in advance split into subtasks that the partners solve independently" (p. 8). Conversely, collaborative learning describes situations "… in which two or more subjects build synchronously and interactively a joint solution to some problem" (p. 8). We take the distinction between the two as indicators of convergent and non-convergent adaptation in that collaborative processes tend to lead more to convergence of shared meanings and higher levels of adaptation through joint activity.

Finally, Scardamalia (2002) describes a program of cognitive, pedagogical and technological affordances that lead groups of learners to achieve collective cognitive responsibility. This canonical process of knowledge-building also attributes success in such learning communities to a set of twelve determinants that include amongst others, *epistemic agency*—participants offer their ideas and negotiate a fit with the ideas of the group, *democratizing knowledge*—all participants contribute to community goals and take pride in knowledge advances of the group, and *symmetric knowledge advancement*—expertise is distributed amongst the group and knowledge is exchanged regularly between group members. Taken collectively, we draw from this literature, a set of indicators in joint activity that are hypothesized to lead to convergent and non-convergent adaptation. Convergent adaptation is described by conversational dynamics where: i) group members share approximately equal speaking time time; ii) turn-taking patterns that indicate a level of synergy as demarcated through group members finishing each other's sentences; iii) members all contribute to the goals of the group collaboratively; iv) individual ideas are negotiated and decisions are made collectively; and v) group members distribute expertise across the group. Conversely, in non-convergent adaptation: i) group members do not share equal speaking time; ii) turn-taking patterns show that members rarely finish each other's sentences; iii) members contribute to the goals in a cooperative manner; iv) individual ideas are not negotiated and decisions are made unilaterally; and v) expertise is localized and not distributed. We apply this convergent/non-convergent framework to small group participation data collected from a professional development activity of curriculum construction described below.

Methods

Context

This work is part of a comprehensive large-scale NSF-funded project under the program title *Innovative Technology Experiences for Students and Teachers* (ITEST). The ITEST program is designed to increase opportunities for students and teachers in underserved schools to learn and apply information technology concepts and skills in the STEM content areas (science, technology, engineering and mathematics). Our project, entitled *Nanotechnology and Bioengineering in Philadelphia Public Schools* (ITEST-Nano) aims to achieve the broader ITEST goals through a curriculum and instruction framework premised on five component variables addressing content knowledge, pedagogical content knowledge and workforce development goals: i) real world science and engineering applications; ii) educational technologies to build content knowledge; iii) information technologies for communication, community-building and dissemination; iv) cognitively-rich pedagogical strategies; and v) STEM education and careers investigations.

There are two parts to the scope and sequence of project activities. The first part entails a three-week 75-hour teacher professional development workshop in the summer where teachers learn to construct and pilot curricular units based on the five component variables of the ITEST-Nano framework. These curricular units are also aligned with school district standards for high science. The summer workshop is followed by the school-year implementation of these units in teachers' classrooms. For this study, we focus on interactions of the teachers in the summer workshop activities conducted in August 2008.

Ten male and six female teachers participated in the workshop from 10 high schools and 1 middle school in the district. The ethnic breakdown of the teachers included 7 White, 6 African American and 3 Asian. Courses taught ranged from grades 8 – 12 in the content areas of physical science, biology, chemistry and physics. The average number of teaching years was 15.8 with a range of 1 to 39 years of experience.

Teachers self-organized into 7 curriculum unit construction groups in the second week of the summer workshop. Based on researcher field notes, we noted some variance amongst the groups in terms of adaptation dynamics, which led us to hypothesize that there were differing processes of convergence occurring. The dynamics of two groups are showcased as representative examples of how convergent and non-convergent adaptation occurred in the small groups and are presented as case studies in the results section.

Data Sources

Several data sources were used in our investigation to understand the processes involved in convergent and non-convergent adaptation. These sources included: (a) participants' application forms in which participants' teaching experiences were listed, (b) pre-workshop surveys from which teachers' prior content and technological knowledge were gleaned, (c) audio-tapes of the interactions during the small group unit construction time (approximately 60 min) where the conversational dynamics were examined, (d) researcher field notes in which observations of pilot teaching in the third week of the workshop and anecdotal participant-researcher conversations were recorded, and (e) post workshop questionnaires from which feedback of their experiences were obtained.

Data Analyses

Several analyses were performed on the data collected. First, from the application form and pre-workshop surveys, a teaching characteristic index (TCI) was calculated for each teacher based on their teaching experiences and characteristics. These characteristics included, number of years of experience, formal leadership role within their school, amount of content knowledge as determined by number and kind(s) of post-secondary degree(s), generalized vs. specialized subjects taught, e.g., grade 8 general science vs. grade 11 chemistry, workshop experience in content domain, initial understanding of content domain, and experience with education and information and educational technologies. Codes for each of the characteristics were assigned 0-2 in most cases. For example, the category of number of years of experience was parsed into the following codes: <5 years = 0; 5-10 years = 1; >10 years = 2. In other cases, codes were assigned as 0 or 1, e.g., no formal leadership role = 0 and formal leadership role =1. An aggregate TCI score was calculated by summing all the assigned category codes for each teacher. We hypothesized that the TCI score could serve as a possible predictor of a groups' adaptation processes in such technology-based science curriculum construction activities, i.e., the more similar the group members' TCI scores were, the more convergent their adaptation processes within the group would be given that their experiences, knowledge and skills were similar.

Convergent and non-convergent processes in our representative groups were investigated using audio-taped discussions, which were transcribed and analyzed according to the set of convergence indicators outlined earlier in the *Processes of Convergence* section. Accordingly, group members' proportional speaking time was determined. Turn-taking patterns in which group members finished each other's sentences were quantified. For the three remaining categories of convergence indicators, instances in which individuals contributed to group goals, instances of idea negotiation, and instances of distributed expertise were noted and compared across the two groups. Other data sources were used to understand group-specific outcomes that contextualized the convergent/non-convergent analytical framework.

Results

Group A, which was comprised of two teachers who worked in the same school and taught different subjects and grade levels, demonstrated a higher level of collaboration from the outset. They were the first group to complete their unit construction and mentioned periodically how much they enjoyed the unit construction time. They co-taught their unit in mostly equal proportions to pilot summer school students in the third week. They followed the project template for their scope and sequence of unit activities and at the time of writing this paper, have also begun to implement the curriculum unit with similar motivation and interest in their regular school year classrooms. By contrast, Group B, which consisted of three teachers who taught at different schools and in different subject areas and grade levels, showed none of the collaborative qualities exhibited by Group A. One teacher in Group B mentioned during informal discussions with one of the researchers that he did not like the unit construction time in the small group. This feeling was also corroborated in his post workshop survey. In addition, during the third week of the workshop, group members voiced concerns about unequal distribution of teaching time when their unit was being piloted with summer school students. Furthermore, their unit was the only one in which the scope and sequence of curricular activities differed from the sample unit templates provided to teachers. Instead, the group used an organization that was only familiar to one of the teachers in Group B. Finally, at the time of writing this paper, it is projected that only one teacher will successfully complete the implementation of their unit.

The analysis of the case groups' characteristics and interactions confirmed our hypothesized difference in their adaptive processes. In Group A, the two teachers had similar TCI scores, which were very high amongst the group totaling 7. In contrast, TCI scores varied across members in Group B where Henry scored 6, Randy scored 5, and Jane scored 4 (see Table 1). For our participant population on the whole, the mean for the TCI score was 5.56, standard deviation, 1.46 and variance, 2.13. We discuss possible relationships of these scores to the respective adaptive processes exhibited in each group in the *Discussion and implications* section.

Table 1: Scores for the Teaching Characteristics Index (TCI)

Group	Teacher	Teaching Characteristics Index (TCI) Score
A	Dana	7
	Angela	7
B	Randy	5
	Henry	6
	Jane	4
C	Cindy	6
	Lucy	5
	Nancy	5
D	Frank	6
	Perry	9
E	Manny	6
	Jake	3
	Jerry	5
F	Andy	5
	Zane	4
E	Mark	5

The sections that follow describe how these groups adapted differently during their co-construction of curriculum units in terms of group members' proportion of speaking time, turn-taking patterns, contribution towards group goals, idea negotiation, and expertise distribution.

Proportion of Speaking Time

By calculating how much time a group member spoke in each group, we found that the percentage of members' conversational participation varied across the two groups. In Group A, both teachers spent almost equal time speaking in their group, whereas teachers' speaking time varied significantly in Group B (see Table 2).

Table 2: Teachers' proportion of speaking time in each group

	Group A		Group B		
Proportion Speaking Time	Dana	Angela	Randy	Henry	Jane
	51.26%	48.74%	60.60%	29.99%	9.41%

Turn-taking Patterns

In order to identify turn-taking patterns, we particularly looked for turns when group members tried to finish each other's sentences or ideas, which we believed was an indicator of convergent adaptation. The results showed that more such turns occurred in Group A's conversation (a total of 26 instances) than appeared in Group B's conversation (a total 6 instances). Excerpt 1 demonstrates an example of the turn-taking pattern of Group A.

Excerpt 1

Angela: I'll just say 2 videos from err…
Dana: Right, "I know nano" and 2nd video, what was it?
Angela: Yes, video is err… she has it in here…

Contributions Toward Group Goals

Members in both groups contributed to achieve their respective group goals but did so in different ways. Specifically, teachers in Group A worked together in a more collaborative manner whereas teachers in Group B worked in a more cooperative manner. For example, Group A's dynamics showed that Dana and Angela often evaluated each other's contributed ideas and made decisions together. The following excerpt shows one example:

Excerpt 2

Angela: Before that, maybe we can start with a kind of video.
Dana: What kind of video?
Angela: Some kind of a nano… we have a …
Dana: Wait, this is our general. We can switch the sequence if you want…
Angela: So I…
Dana: Oh you mean put a video in? Ok. So which one do you want?
Angela: This is the one "take the nano-journey" (pointing to the computer screen). That's the one…
Dana: Yeah.

The above excerpt shows an example of how Dana took Angela's idea to insert a video into their unit and evaluated whether it was the right place to insert it. They showed a manner of collaborative work in which they treated their curriculum construction as a social action in which the group members worked together to produce a joint solution.

In Group B however, Randy, Henry and Jane contributed to the group work in an isolated way without much group interaction. The following excerpt demonstrates a typical way in which their group communicated:

Excerpt 3

Henry: Could we put this (a website Henry found) in now?
Randy: Yeah. What's that?
Henry: I just want to see if this could be put in before …, just so we have it. Put it right in.
Randy: Right. Where do you want to put it?
Henry: Or, it has to go under … medicine, right there.

In this excerpt, Henry makes a contribution by providing a website resource to the group. Instead of considering whether the content was appropriate or if it was the right place to insert, Randy took Henry's idea without giving any feedback or evaluation. Throughout the transcript, group dynamics indicated similar instances of idea contribution without evaluation. Thus, Group B exemplifies what Dillenbourg and Schneider (1995) describe as cooperative action in which partners solve problems independently.

Idea Negotiation and Decision Making Processes

Another dynamic we investigated was how groups negotiated agreement on individual member's contributions of ideas and processes of decision-making. Results showed that the two groups differed again in these fundamental idea negotiation dynamics. For Group A, both teachers individually contributed ideas but shared responsibility for decision-making. The following excerpt illustrates this dynamic:

Excerpt 4

Angela: And maybe we can ask them on day 3 at the end, we can ask them like what do they want to put in their podcast. So write it down.
Dana: Right.
Angela: So at the end of day 3. So they write it down. So when they come… Thurs when they come in, when they prepare the …
Dana: (Flipping through her notes) Oh, we did, we have them for day 4… Discussions for pros and cons for podcasting. Let's just put that at the end of day 4.
Angela: Day 4 is the day we do it. Well, that's fine.
Dana: Oh ok. So I think we're good.

This example shows the process of group negotiation before reaching an agreement. First, Angela proposed to have the students put down their thoughts for their podcast content on day 3. Dana then disagreed by showing Angela that they had planned to discuss pros and cons for podcasting on day 4. Angela changed her initial idea and agreed to move the activity to day 4. Although this excerpt does not demonstrate evidence of reasoning that might have convinced each other (the process of reasoning can actually be heard in earlier parts of their discussion), it does show that both teachers held equal responsibility in the group decision-making process.

In Group B, the group members did not show much individual idea negotiation during their group curriculum construction. The decision-making responsibility fell on the person who initiated an idea and the other group members did not provide feedback or alternative ideas. Thus there was no negotiating process before a decision was made, which we believe contributed to a dynamic of non-convergence within the group. For example in excerpt 3, we saw how Henry made an individual contribution in terms of including a web resource in their curriculum and also unilaterally decided where in the scope and sequence, the website should be placed.

Distribute Expertise

We believe that how teachers leveraged individuals' expertise within their groups indicated their type of convergence. Analyzing the groups' transcripts, we found the two groups differed in their approaches to expertise distribution. Specifically, Group A showed a collective expertise distribution, e.g., knowledge sharing or expertise was directed back and forth between members, while Group B illustrated a localized or compartmentalized approach, e.g., knowledge sharing or expertise occurred in only one direction. The following excerpt shows how Dana and Angela exchanged their respective expertise with each other.

<u>Excerpt 5</u>

Dana: What their knowledge content is before we move into this? Because how much do we really go into it… We can just give them a general…
Angela: Yeah, the general… like "What is matter?"
Dana: Right. Right.
Angela: What is the property? What are the physical properties…
Dana: Right. What is the difference between physical and … so basically the difference between the physical and chemical properties, right?
Angela: And then, the 3 phases of matter.
Dana: Right.
Angela: And how they change? … and we can talk a little bit about the pressure…
Dana: Ok right. So we are going to talk about pressure, and the needles. So what's going to happen is we are going to talk about pressure. I'm going to give them balloons…

The above example shows that Dana first suggested that they should consider teaching the students some general content knowledge before their planned activities. Angela then brought into the conversation, her expertise on the topic of matter in physical science. At the same time, Dana also contributed her expertise based on her understanding even though her expertise fell in biology. This interaction augmented the group's collective knowledge about the topic of matter and helped to make progress in the curriculum construction.

In contrast, Group B showed more of a unidirectional expertise distribution, which often led to a didactic process of transferring knowledge. In the excerpt below, Henry appeared to teach his fellow members about the concept rather than contributing to a collective discussion.

<u>Excerpt 6</u>

Henry: I just made my point again. If you take 50 milliliters of alcohol and 50 milliliters of water and put them together, we will have how many liters will show on.
Randy: Like 99 something like that.
Henry: Well, 97.
Randy: Ok.
Henry: Why?
Jane: Because some goes up in the air?
Henry: No. Because the m … they slip into each other.
Jane: The m?
Henry: The atoms of the alcohol rubbing alcohol, slip into … The way is this … with the scale, the weight remains the same between the two,

In this conversation, Henry acted like an instructor teaching the other two members about the alcohol and water experiment. After this exchange, the group went on to a different topic rather than continuing the discussion.

Discussion

Our study directly responds to calls for using reform strategies in technology-based educational programs that can account for the complexities that influence their successful implementation in practice (Coburn, 2003; Dede

& Honan, 2005; Elmore, 1996). We take the view of *Small Groups as Complex Systems* theory (Arrow et al., 2000) that evolves from a social psychological heritage and considers group dynamics as emerging products from complex and adaptive systems. We have used the complex systems concept of adaptation as a lens for understanding how and why some teachers in such educational programs are better able to adapt to program requirements (Yoon & Klopfer, 2006). To investigate this, we constructed a framework that examines the parameters under which group dynamics can lead to more or less adaptive outcomes. Based on seminal CSCL research, we have hypothesized that processes of convergence exhibited in teacher group interactions can predict these adaptive outcomes and present two cases that illustrate instances where convergence and non-convergence occurred.

The analyses of the small group unit construction discussions showed differences in the two case groups' convergence and non-convergence processes, which represent different types of adaptation of immediate individual feedback to the program requirement in a collaborative context. One major difference lies in whether the group communication structure was hierarchical or decentralized (Greeno et al., 1998). Teachers in Group A shared approximately equal speaking time and demonstrated turn-taking patterns where members were heard finishing each other's sentences a comparatively higher proportion of the time. This communication structure can be understood as decentralized and may have, in part, led to convergent adaptation. In contrast, Randy in Group B led much of the communication, speaking for more than half of the discussion time and instances where members finished each other's sentences represented less than one-fifth of the proportion found in Group A's discussion. Thus, the communication pattern can be viewed as hierarchical rather than decentralized and may have led to non-convergent adaptation.

In addition, the two groups illustrated the distinction between collaborative (Group A) and cooperative (Group B) task completion (Dillenbourg & Schneider, 1995) and showed differences in how members contributed to group goals, idea negotiation and decision making processes. Group A again demonstrated higher level functioning in all these measures compared to Group B. These findings are similar to those found in other studies where consensually driven explanations (Roschelle, 1992) and knowledge-building through epistemic agency (Scardamalia, 2002) led to increases in shared meanings and collective responsibility of cognitive tasks. Finally, in order to complete the curriculum construction, teachers in Group A contributed their expertise in a distributed way as opposed to the unidirectional pattern found in Group B's discourse. This is an example of what Scardamalia (2002) has called *democratizing knowledge* and *symmetric knowledge advancement*, both of which have been shown to lead to higher levels of knowledge building. When taken collectively, we can see how processes of convergence and non-convergence influenced differential adaptive outcomes that explain why Groups A and B experienced different levels of success in the curriculum construction activity as explained in the first paragraph of the *Results* section.

Human and social adaptation is influenced by individual characteristics including knowledge, goals, experience, preferences, interests, and surrounding environment (Brusilovsky, 2001). In this study, we examine the parameters that benefit teachers to collaboratively seek better strategies as they make transitions from one pedagogical paradigm to the next. With respect to the teaching characteristics index calculations presented in Table 1, we were interested in understanding whether we could in some way predict *a priori* which group configurations based on their teaching experiences would lead to convergent adaptation. There is evidence to show that the more similar the TCI numbers were between group members, the more likely it was that the groups' dynamics would result in convergent adaptive outcomes. While we showcased Group A in our analyses, Groups C and F also showed similar patterns and the opposite was true for Groups E and F in terms of non-convergent adaptation.

Implications

We are in the process of collecting data from all of our teacher participants' implementations of the co-constructed curriculum units during the school year and expect to conduct further analyses to compare teachers' classroom implementations as well as student learning outcomes where we hope to find correlations between teachers' TCI scores and their groups' adaptation patterns. We also intend to conduct similar analyses with new cohorts of teachers attending our summer workshops in 2009 and 2010. However, as reform-oriented professional development learning science researchers, we find value in taking a more microscopic approach to understanding group adaptation processes in order to structure curriculum construction activities that will maximize potential for future success. From the results of this study, we are now in the process of identifying group activities that teachers can participate in where convergent processes are *modeled* and *practiced* prior to working in their curriculum construction groups. Furthermore, rather than allowing teachers to self-organize into groups, we are considering pre-assigning members to specific groups based on similarities in TCI scores with the intension of collecting more robust evidence that can demonstrate the efficacy of this method and justify its application in constructing professional development activities.

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Democratizing Design: New Challenges and Opportunities for Computer-Supported Collaborative Learning

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Abstract: The fundamental challenge for the next generation of Computer-Supported Collaborative Learning (CSCL) systems is to contribute to the invention, fostering and support of cultures of participation in which humans can express themselves and engage in personally meaningful activities. New models for knowledge creation, accumulation, and sharing are needed that allow, encourage, and support all participants to be active contributors in personally meaningful activities. In our research, we have explored and contrasted two different models: MODEL-AUTHORITATIVE (based on strong input filters, relatively small information repositories, and weak output filters) and MODEL-DEMOCRATIC (based on weak input filters, large and diverse information repositories, and strong output filters to find relevant and reliable information). We postulate that MODEL-DEMOCRATIC democratizes design, requires support for meta-design, and fosters social creativity thereby creating new challenges and opportunities for computer-supported collaborative learning. Examples from different lifelong learning settings based on MODEL-DEMOCRATIC are described and analyzed and some general findings are derived and discussed.

Introduction

Consumer cultures based on the *industrial information economy* (Benkler, 2006) have been focused on creating finished goods such as complete software systems, movies, curricula, lectures, and information repositories. Cultures of participation based on the emerging *networked information economy* are democratizing the design and evolution of rich collaboratively constructed information environments (von Hippel, 2005) by creating *socio-technical environments*. These fundamental changes create new challenges for CSCL (Brown, 2005) by breaking down the barriers and distinctions between designers and users, teachers and learners (creating "communities of learners" (Rogoff et al., 1998)), consumers and producers (creating "prosumers" (Tapscott & Williams, 2006)) and between professionals and amateurs (creating "prom-ams") allowing and supporting humans (not all of them, not at all times, and not in all contexts) to be and act as *active contributors in personally meaningful activities* (Fischer, 2002).

The implications for CSCL are that the computer support (the "CS" in CSCL) should focus on innovative media and new technologies that do not deliver predigested information to learners but provides them with the opportunity and resources for engaging in self-directed learning, and that collaborative learning (the "CL" in CSCL) allows all participants to engage actively in framing and solving of authentic problems, have a voice in social debates and discussions, and create shared understanding. The paper explores and provides further evidence for the claim put forward at CSCL'2007 that *"CSCL is not thinking radically enough (1) by accepting too many established approaches and organizations (e.g.: a theory of human learning based solely on school learning is too limited), (2) by not embracing new learning opportunities (e.g.: exploiting the unique opportunities of social production in which all learners can act as active contributors in personally meaningful problems), and (3) by not providing broader conceptual frameworks for learning in the 21st century"* (Fischer, 2007).

Design Methodologies for Socio-Technical Environments Supporting CSCL

Design (Simon, 1996) has emerged as a fundamental topic of great importance for the world in the 21st century explored by research communities in different domains (e.g.: software design, urban design, design in the creative arts, design of learning environments, and collaborative design efforts). Most design methodologies (including *user-centered design* approaches and *participatory design* approaches) have focused primarily on activities and processes taking place at design time in the systems' original development (e.g.: a teacher preparing an instructionist lecture of a website for broadcasting information), and have given little emphasis and provided few mechanisms to support systems as living entities that can be evolved by their users. But despite the best efforts at design time, systems need to be evolvable to fit new needs, account for changing tasks, deal with subjects and contexts that blur different contexts, be coupled with the social environment in which they are embedded, and incorporate new technologies. *Meta-design* (Fischer & Giaccardi, 2006) is focused on "design for designers". It creates open systems at design time that can be modified and evolved by their users, requiring and supporting more complex interactions at use time. Open systems allow significant modifications when the need arises. The successes of collaborative knowledge construction, open source software systems (Raymond &

Young, 2001), and open content environments (Benkler, 2006) have demonstrated that given the right conditions, design through the collaboration of many can create new kinds of systems.

Different Models for Knowledge Creation, Accumulation, and Sharing

The process of knowledge creation, accumulation, and sharing in society has undergone major changes. Initially, knowledge was accumulated in the heads of people and communicated by tales, stories, and myths. The oral tradition has been replaced by a written tradition that allows people to permanently record thoughts and widely distribute them (Ong, 1982). Information technologies have created fundamentally new opportunities including the latest shift from professionally dominated consumer to cultures of participation which democratized design in numerous design domains.

Professionally Dominated Design Cultures: Model-Authoritative.

Professionally dominated design cultures (see Figure 1) are characterized by a small number of experts (such as teachers) acting as contributors and a large number of passive consumers (such as learners). In such cultures, strong input filters exist based on:

- substantial knowledge is necessary for contributions (e.g.: the in-depth understanding of established fields of inquiry or the need to learn specialized high-functionality tools); and
- extensive quality control mechanisms exist (e.g.: the certification of professionals or low acceptance rates for conference and journal articles); and
- large organizations and high investments for production are required (e.g.: film studios such as Hollywood, newspaper production facilities);

A consequence of the strong input filters preventing and rejecting contributions is that relatively small information repositories are created.

The *advantage* of this model (this is at least the basic underlying assumption) is the likelihood that the quality and trustworthiness of the accumulated information is high because the strong input filters will reject unreliable and untrustworthy information. Based on the smaller size of the resulting information repositories, relatively weak output filters are required.

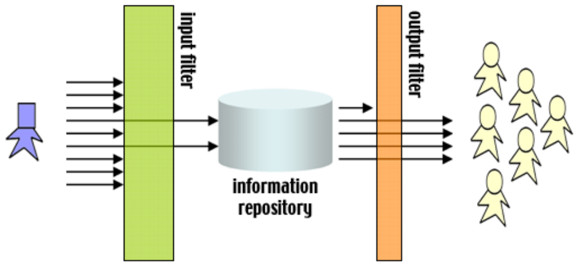

Figure 1. MODEL-AUTHORITATIVE underlying Professionally Dominated Cultures

The *disadvantage* of this model is that it greatly limits that “all voices can be heard”. Their intake is limited because with only a small number of contributors too many views are unexplored and underrepresented because the controlling mechanisms behind the input filters suppress broad participation from different constituencies. In our complex globalized societies, no one knows everything and concepts such as symmetry of ignorance, conceptual collisions, and epistemological pluralism should be seen and supported as unique opportunities to support social creativity. Relevant information and divergent opinions (which may be of great value not at a global level but for the work of specific individuals) will often not be included in the information repository. Most people are limited to accessing existing information, denying them a voice even in the context of personally meaningful problems and in situations in which specialized idiosyncratic knowledge would represent a unique contribution.

Democratized Design Cultures: MODEL-DEMOCRATIC.

Democratized design cultures (Fischer, 2002; von Hippel, 2005)) (see Figure 2) can be characterized by weak input filters allowing users not only to access information but to become active contributors by engaging in *informed participation*. The weak input filters result in much larger information repositories (with information repositories such as the World Wide Web being the prime example).

MODEL-DEMOCRATIC on the *technical* side requires powerful tools for creating content (such as Wiki substrates and end-user development environments), for organizing content (such as supporting collections), and for distributing content (such as powerful search capabilities and recommender systems). On the *social* side, it requires active contributors (who master the design tools and who are motivated to contribute), curators (who organize the large information repositories) and docents (who assist in helping learners to identify and locate relevant information). Embracing a social-technical perspective, our research activities focused on MODEL-

DEMOCRATIC are grounded in the basic assumption that technology alone does not determine cultures of participation but that it creates feasibility spaces for them.

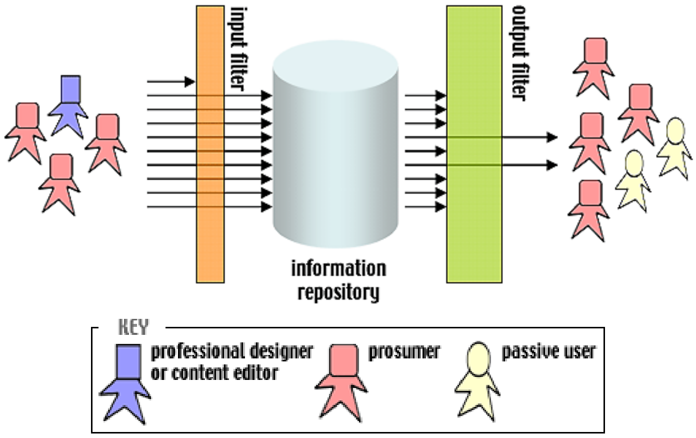

Figure 2. MODEL-DEMOCRATIC underlying Democratic Design Cultures

The advantages and disadvantages of the two models are to some extent reversed. Major limitations of the second model are the potentially reduced trust and reliability of the content of the information repositories based on the weak input filters. The amount of available information is exploding, and since too much information consumes the true scarce resource of human attention, the large information repositories will be a mixed blessing unless we are able to develop strong new output filters (e.g.: powerful search mechanisms to find relevant information, collaborative filtering, recommender and tagging systems, and user and task models to personalize information).

Examples of CSCL Environments Based on Model-Democratic

New developments over the last few years supported by Web 2.0 architectures (O'Reilly, 2006) (Benkler, 2006; Tapscott & Williams, 2006) have created numerous environments providing interesting examples for MODEL-DEMOCRATIC. All of these environments are dominated by user-generated content and all participants have the opportunity to act simultaneously as "teachers" and "learners" and learning takes place by contributing, by analyzing, reflecting, and evolving other participants' contributions, and by supporting a rich ecology of different roles (including: contributors, local developers, gardeners, curators, docents, raters, taggers) and allowing participants to migrate between these roles.

Some of the most prominent examples that we have analyzed: LINUX, WIKIPEDIA, SECOND LIFE, FLICKR and YOUTUBE, *SCRATCH* programming environment, *SAP Developer Network COURSES-AS-SEEDS, 3D WAREHOUSE*, and *CREATIVEIT*. Over the last few years, we have investigated specifically the last *four examples* of this list and the last two will be briefly described.

SketchUp, 3D Warehouse, and Google Earth: Sharing 3D Models

Google is interested in modeling the whole world in 3D and uses Google Earth for exploring this world. This objective cannot be achieved by a development team at Google alone. The most feasible approach is to engage the whole world in this major undertaking with MODEL-DEMOCRATIC. To do so poses a number of challenging problems for participants acting as active contributors. They need to learn ***(1)*** *SketchUp****,*** a high-functionality environment for 3D modeling (http://sketchup.google.com/), and (2) the mechanisms how to share 3D models by uploading them from SketchUp to the 3D Warehouse and (b) how to download models from the 3D Warehouse and from SketchUp and view them in Google Earth (if the models have a location on earth). In order to motivate and empower enough people, we have explored in close collaboration with researchers from Google new learning mechanisms for SketchUp to allow everyone who wants to contribute to learn doing so by reducing the "thickness" of the input filters. The *3D Warehouse* (http://sketchup.google.com/3dwarehouse/) is an information repository for the collection of models created by all users who are willing to share their models containing ten thousands of models from different domains. It supports *collections* to organize models and supports ratings and reviews by the participating community. It lets viewers connect with the owners of models. It has *weak input filters* (such as content policies), mechanisms to ensure the quality of user contributions (such as tagging and ratings), and an *emerging set of output filters* (such as search support and different sorting algorithms). It is integrated with SketchUp (as the design environment) and *Google Earth* as a viewing environment which has the capability to show 3D objects that consist of users' submissions and were developed using SketchUp.

Distributed Scientific Communities.

We have designed and seeded a wiki-based socio-technical environment (http://swiki.cs.colorado.edu/CreativeIT) to foster and support the emerging CreativeIT Community, consisting of participants (researchers, artists, graduate students) in the NSF research program on "Creativity and IT" (http://www.nsf.gov/pubs /2007/nsf07562/-nsf07562.htm). The unique challenges of supporting this specific community with MODEL-DEMOCRATIC are that people working in interdisciplinary projects or in niches of their disciplines are often isolated in their local environments unaware of relevant work in other disciplines. Based on this research, we have developed a deeper understanding of how technical and social environments can be changed through design interventions. We are in the process of assessing and collecting a variety of data (using tools such as Google Analytics as well as our own tools) to gain a better understanding of the value of recording implicit interactions versus engaging participants in explicit activities (such as tagging, rating, commenting).

Implications

Harness Social Creativity.

Cultures of participation challenge the assumption that information must move from teachers and other credentialed producers to passive learners and consumers. As long as only experts (including: teachers, professionals in different disciplines, commercial producers of software and movies, etc) can determine what is right and worthwhile to be published, we will never be in a position to harness people's social creativity and local knowledge. Arguing that MODEL-DEMOCRATIC supported by meta-design opens the opportunity to harness social creativity, we do not imply that it is the preferred model for all human activities. We need a deeper understanding under which conditions and for which kinds of activities MODEL-AUTHORITATIVE is the preferred model rather than MODEL-DEMOCRATIC and the views of experts maybe more relevant, reliable, and insightful compared to the "wisdom of crowds" (Surowiecki, 2005).

Quality of Information Repositories.

How do we know that the content produced with MODEL-DEMOCRATIC by widely dispersed and qualified individuals is not of substandard quality? There are many open issues to be investigated including: (1) errors will always exist; the questions will be which model is better suited to deal with errors over time; how do knowledge workers acquire the important skill to be always critical of information rather than blindly believing in what others (specifically "experts") are saying?; and (2) ownership may be a critical dimension: the community at large has a greater sense of ownership and thereby is more willing to put an effort in that errors will be fixed.

Motivation for Participation.

Being an active contributor requires more effort and more time than being a passive consumer. In order for MODEL-DEMOCRATIC to be a viable alternative, we have to explore the fundamental question: *what motivates people to participate* (Renninger, 2000)? Active contributors are often domain professionals, competent practitioners, and discretionary users and should not be considered simply as naïve users.

Supporting the "Long Tail".

In systems supported by MODEL-DEMOCRATIC there is something for everybody. Not all active contributors are equally creative but *most people have some unique expertise* residing in the "Long Tail" (Anderson, 2006; Brown & Adler, 2008) which is more likely to become externalized and documented with weak input filters. Providing platforms for user-generated content and motivation for participation, Long Tail environments can achieve coverage that a small team of professionals is unable to generate (as argued and demonstrated with the examples described earlier).

Conclusion

Cultures supported by MODEL-AUTHORITATIVE encourage consumption of polished, finished goods. The emergence of democratized design cultures as characterized by MODEL-DEMOCRATIC and supported by Web 2.0 environments provides a richer set of cultural forms and practices and requires new forms of computer supported collaborative learning. Whether the *advantages* of democratized design cultures (such as: extensive coverage of information, creation of large numbers of artifacts, creative chaos by making all voices heard, reduced authority of expert opinions, shared experience of social creativity) will outweigh the *disadvantages* (accumulation of irrelevant information, wasting human resources in large information spaces, lack of coherent voices) will require more investigations and explorations.

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The Process of Digital Formalization in Sociotechnical Learning Communities – Needed or Overloaded?

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Abstract: The Web 2.0 is often characterized by an informal participation, which means a free cooperation of as many as possible without any restraints from organizations, processes, or technical platforms. In contrast to public communities, an official organization like a company consists of rather formal structures which define what a member should do and how to fulfill a task by assigning a role. If such a formal organization supports a community, does the balance between informal and formal structures will change? This short paper presents the results of a field study about a socio-technical community called 'InPUD' which is part of a faculty. The main conclusion is that a specific degree of digital formalization in online groups is needed for successful online structures and sustainability. By using new media like Web 2.0, the balance between informal and formal structures in institutions will be changed.

Introduction

In the past decade, new forms of socio-technical phenomena emerged, e.g. online communities and virtual networks. New IT applications like Web 2.0 transform social systems (e.g., social groups, universities) into socio-technical systems, where socially and technically supported relationships are highly interwoven. The Web 2.0 is often characterized by an informal participation, which means a free cooperation of as many as possible without any restraints from organizations, processes, or technical platforms.

Recent studies of internet-based communication show trends that social structures in online communities evolve. For example, Viegas, Wattenberg, Jesse & van Ham (2007) studied the Wikipedia community and found an increase of coordination activities from 2003 to 2007. Despite the potential for anarchy in Wikipedia, "the Wikipedia community places a strong emphasis on group coordination, policy, and process" (Viegas et al., 2007, p. 1530). Viegas, Wattenberg & Kushel (2004) also show the behavior of Wikipedians in conflict situations: the most activity in Wikipedia is not writing new articles but controlling the quality of written articles, to rid new articles of vandalism and to act as mediator for two or more authors (e.g., discussions on spelling). To summarize, the studies reveal that the social structure of an online group changes over time.

Is this observation of a community's change also valid for socio-technical communities, does the structure change over time? In contrast to general web based, online or virtual communities in the public such as Wikipedia or Facebook, a socio-technical community (STC) is part of an official organization consisting of formal structures which define what a member should do and how to fulfil a task by assigning a role. First, the theoretical framework, second the case of the 'InPUD-community' and third the qualitative research method will be described. Finally, the results on the changes evoked by InPUD's dynamic will be illustrated.

A sociotechnical community and its relation to the official organization

In this short paper, a socio-technical community (STC) is defined as follows: A STC – depending on content, lifespan and group size (Preece, 2000), and part of an official organization (e.g., company or university) – consists of a structure of informal ties, social relationships of people sharing same topics or problems (Wenger, McDermott & Snyder, 2002) fostered mainly by computer-mediated human interactions (e.g., a knowledge community about study information at a university or faculty). A STC is different from public online communities since a STC delivers a kind of interaction space for enabling informal communication between members and others within an official formal organization, for instance, a university, or a faculty. According to Jahnke (2009), such a community has the potential to reduce social complexity and information overload from the official organization, and makes it easier to get only such information what a member need at a given time.

Wenger et al. describe in their book about "cultivating communities of practice" how to manage knowledge within a company. The authors analyzed four in-depth cases of large firms mainly through observation and qualitative interviews. Their research has leaded them to conclude a description of seven principles for cultivating communities including different degrees of community participation (p. 57). These degrees include: the core group, active members, peripheral people, outsiders and the role of a coordinator. Is this general model also valid for a STC in a university, or will the structure change over time?

Formal and informal structures

A social structure (formal, informal) is a combination of social relations as well as human (inter-)actions. Formal structures are characterized by conventional forms of behavior, and established conventions, for example, behavior which is formally bound by a work contract and a job/task description. By assigning a role, the formal organization defines what a member should do and how to fulfil a task.

In contrast to work groups in companies, where the group members are formally bound, a STC consists of informal connections between members (Lesser & Prusak 1999). Informal structures are rather casual, unofficial, loose and not triggered by any rules (e.g., informal get-together).

According to Jahnke, Ritterskamp & Herrmann (2005), four categories can be used for the analysis of computer-supported structures: assigned position held by individuals, assigned tasks/activities, assigned expectations, and role-playing (defined as a human interaction process). This article concentrates the description of the analysis on two aspects: position and interaction patterns.

- *Position*. The position means the member's position in the online community in relation to others, also known as network position and social relations. Social relations in online networks exist particularly through different patterns of online communication (e.g., who communicates with whom).
- *Interaction*. Computer-supported human interactions are built and changed by individuals by way of their action and communication. The perceivable repetition of interaction patterns can indicate the structure.

A change from informal to a formalized structure is defined as the process of *digital formalization* including changes of social and technical formalizations. When the study show changes in the social dimension like more formal roles, more coordination activities, one can say it is on its way to a social formalization. When the study shows technical changes (e.g., increased complexity of technical features; technical regulation), one can say it is the way of a technical formalization. The research question is: What forms of structures within a STC emerge?

Case study

With regard to the learning paradigm (e.g., shift from teaching to learning; Barr & Tagg, 1995), information and participation are important key factors for designing technology-enhanced learning communities. Different tools supporting the (co-)creation, communication and annotation of information can be used. The support can takes place in different ways and for different scenarios in teaching and learning environments. Either one could focuses on the teaching scenario itself, for example, the communication opportunities within a tutorial, a lecture, or a course, or one could support communication which takes place after leaving the lecture hall and in the time 'between' several courses. A third scenario combines both cases. In any case, such scenarios include for example Web 2.0 communication tools, a discussion board or other applications (e.g., blogs, or tagging tools).

An example that combines both is the InPUD-community at the Faculty of Computer Science at the Dortmund University of Technology (in more detail Jahnke, 2009). The InPUD-community (http://inpud.cs.uni-dortmund.de) launched in 2002 includes an overview of all classes and offered courses. The community provides information about the lectures, including any tutorials that are being held (and when they are being held), course materials, notices for examinations, lecturer contact information and - that is important - several free discussion boards about courses as well as study services (e.g., 'how to study successfully') are also part of it. The communication tool is used within lectures and about lectures. It range from discussions about course content, definitions or solutions for exercises to organizational issues, e.g. where and when is the next learning group, what could be the content of the examination, or discussions about the teacher's quality. The InPUD-community differs from public communities which are built in people's spare time and which are not a part of a company. InPUD is an extended part of an official organization supplemented to the formal structure. The InPUD-community is characterized by a large size. The primary content of the InPUD-community is knowledge sharing about computer science courses as well as study management issues.

Research design

From 2001 to 2008, we conducted a long-term study based on the design-based research DBR (e.g., Reeves, Herrington & Oliver, 2005), which consisted of several phases of analysis (reflection) and action (interventions) which were alternated and interwoven (cycle of activities). The aim of such a qualitative research design is to understand the social or socio-technical situation as well as to improve its quality. In our case, the study wanted to create a living community system (practical aim) and analyzed if/what new social structures emerge. The major goal of DBR is to generate theory to solve practical problems. Researchers fulfil several roles like researchers, designers, or practitioners.

The specific research phases included eight phases of data collection (in-depth interviews with students, teachers, study managers; quantitative questionnaire, ethnographic online observations, statistics, formative evaluation methods) as well as interventions (including design, development and implementation).

We are using this qualitative paradigm to refer to our field study in which interviews and other forms (e.g., participant observations; written communication in online boards, interviews, talks with stakeholder) from a rather small number of cases are closely read, analyzed, and interpreted. One essential goal was to find new coherences to understand (the possible emergence of) computer-supported social structures and (possibly new forms of) computer-mediated human interaction. We did not have measurable variables before we started our research, since we did not have a clear picture of what was going on in socio-technical communities at universities. In our prior assumptions we expected to observe a change of the structure. However, we had no ideas in which degree or forms it could change. We had the assumption that socio-technical communities are rather informal and would stay at this level over time. Surprisingly, what we learned is: a socio-technical community changes its structure from an informal to a rather formal structure at least in some forms. The results presenting in this paper produces both practical educational interventions and theory generation including measureable variables that can be checked in a follow-up research.

Results

The analysis asked about the change of informal and formal structures in online communities that depend on technically mediated communication. This article describes the results on two aspects: changing positions and interaction patterns.

Ad a

We observed that the members of the InPUD-community develop social relations online. Some people, the core of the community, even built strong ties, e.g. the same community members met habitually at the same discussion board at the same time. Some months later, the relational structure has changed over time.

Since InPUD's launch in September 2002, the number of users has increased steadily. Today, in September 2008, more than 1,470 individuals had an account. This is 73 percent out of 2,000 enrolled students at the faculty. A quantitative survey in December 2008 confirmed the trend: more than 70 percent of the students labeled themselves as a community member ("I am a part of the community").

The number of contributions per individual in six posting categories over the entire period from 2002 to 2008 (September) was increasing. Some members posted more often than others A core of about 270 individuals provided contributions regularly, ranging from 26 to 483 postings per individual. The core members are especially the 'early adopters' and in this sense (from our today viewpoint) the 'elders'. These people have been active since InPUD's early years. The other active members made postings in the range from 1 to 9 and 10 to 25. These members can be described as regulars, but also include novices and visitors (e.g., high schools students, students from other universities).

A split of the numbers of contributions in relation to 2003, 2004, 2005 and 2006 (we excluded 2007 as this year is very similar to 2006 and for 2008 we only have data for September) show a differentiated picture. It has to be stressed, that an average member posted more in 2003 and 2004 than in 2005 and 2006. For example, in 2003 sixteen individuals posted 101 to 200 contributions (each of them!) and in 2004, 21 users posted a similar amount. In comparison, just 11 users in 2005 and 6 members in 2006 contributed so often. In summary, the large number of registered users indicates that the relational structure has changed over time to *more contributors* but the *quantity of contributions per individual has decreased*.

According to the quantitative change, we also observed changes in the forms of communication. We observed the time between questions and answers, and it looks like that the positions (who communicate with whom and in which time span) are changing over time. One finding from the questionnaire distributed in 2003 was following: just in its beginning, 93 percent of the students were familiar with InPUD. Particularly in the first stages of InPUD's development, students were often the only ones who answered an open question. At that period, the community was an informal large group. The active students helped other members and told them "how to ask questions" or informed them that "that question has already been answered on board 6". In the phase of growth, teachers became part of the communication process and affect the STC. A typical example is a question posted in a discussion board of a lecture with 80 students in 2007. The question of student A was posted at 4.27 pm and concerned the question of-what a 'socio-technical system` is. The first answer was given by student B at 4.34 pm – only 5 minutes later. Student A replied and posted a comprehension question at 4.53 pm. Student C posted a comment at 5.30 and student A replied at 5.55 pm, writing "Now, it is clear to me. Thank you!". Just 1 hour and 28 minutes elapsed between the posted question and the acknowledgement of understanding. The following day at 11.48 am, the teacher confirmed the ideas posted by student C and added new ideas and information. Thirty minutes later, student A thanked the teacher as well as the other users again. In contrast to the earlier phases of InPUD, the STC enables its members in the growing phase to get in contact with people in different positions – when needed. But it also indicates that the teachers want to have a kind of control about the communication process. With the teacher's presence, the process of formalization has begun.

A next example describes the change of the typical communication phrases in InPUD. Members who interacted and helped others, also said "thank you" or wish "good luck with exams". The more the community grew, the more communication phrases were observable. We observed a thread without any factual information just with the topic 'acknowledgements'. A student wrote "I only want to say 'good luck' for all of you for the written examination, and thanks again!" And some members answered with similar expressions and showed their appreciation. Some discussions also drifted from the content to personal interests (e.g., "where do you live?”). Although InPUD is large anonymous group, the STC gives the students the chance to keep in touch with people who share the same problems. We call this phenomenon ‘computer-mediated social proximity’ since it was triggered ‘through’ the medium of the technical system (especially through discussion boards for lectures and study management issues). The comparison of three surveys in the beginning (2002), in the middle (2003) and six years later, in 2008, showed a significant difference. The online proximity has increased.

Ad b

The data shows that the community members were primarily students from the Faculty of Computer Science at Dortmund University of Technology, at least in the early years, between 2002 and 2004. From 2005 to 2008, individuals in formal positions participated more often than in the earlier phases.

In the initial growth phase (2003 to 2004), new online interaction patterns (beginning of new roles) emerged, for example active people took the role of promoters, conclusion-makers, decision-initiators and conflict mediators (Jahnke, 2009). More and more, the informal online group has been formalized by its own social structures. The communicative style – also known as ‘netiquette’, a set of rules governing the behavior of members – affected the structure of the community. One such case in InPUD was as follows: a student was annoyed about a lecture and asked in an agitated tone: “What the hell does the professor do? I don’t understand anything!” In response, some students generated a “true vote for the mood in our lecture”. Some members commented on the ‘unexpected’ remark as “not okay” (“You are not striking the proper tone!”), others ignored that behavior, did not answer, and opened a new thread.

In 2002, there were only 5 formal moderators online. The formal moderators, a task that academic personnel are obliged to perform, usually did not moderate often. For example, it ranged from only 2 to 50 contributions per year. In the interview phase in 2003, students told us that a Yahoo group for Computer Science students in Dortmund existed. They described that participation had decreased since InPUD was launched. “There is also a Yahoo group for computer science students in Dortmund. But it’s just an independent separate group. Open, no structure – it’s just a student self-organised group. Not really helpful. This online group [Yahoo] hasn’t a moderator who is from outside; a moderator who isn’t from the same group. InPUD has always at least one moderator from the faculty staff. Well, they could actively do moderation more often. But they are there, that’s better than nothing” (quote of a student, 2003).

During the stage of sustainable development in 2005 to 2006, more and more formal roles became part of InPUD. Formal roles are, for instance, study managers, professors, lectures, academic staff, and people from the faculty office. This increased to 16 from 2003 to 2004, in 2005 to 2006 this further increased to 45 moderators. It can be named as a specific degree of social formalization. One student said: “InPUD has got more and more professors, lecturers, and tutors than two years ago, and they are more active than in 2003. That’s good.” [answer of a student in summer 2007].

In the growing phase, the role names of the academic staff were labeled automatically (when they were logged in). This ‘online role presence’ can be named as a specific degree of technical formalization. For example: “Mr. Miller, Advisor of Study Management” or “Mrs. Smith, Lecturer for Human-Computer-Interaction”. The names of the formal roles were visible when members communicate online. One student said: “When I can see who gives me the answer, a person from my faculty or a study manager, I guess this information is often a more valuable contribution than a student’s answer”. The visible presence of role names affected the help-yourself behavior of the informal student’s group. It regulated the social structure and might have improved the frequency of webpage requests, contributions of students and ultimately encouraged the development and evolution of the community.

An interesting result is that experts in particular study counselors, researchers, teachers and academic staff told us a totally different expectation in 2002: “Software tools again and again – that’s not the right way”, “We have enough information on our websites”, “A community is not helpful”, “It doesn’t work”. Even one professor said “It’s more important to initiate face-to-face communication – before we cultivate a web based thing”. Apparently the views of experts changed as the student moderation in the informal community proved its added value. This shift from merely informal activities to more formal roles and more activities can be explained by the increased adoption of InPUD from 2004-2008. Obviously, the balance between informal activities and formal roles were changing.

Discussion

The results indicate that the balance between informal and formal activities has changed. The STC called InPUD evolves from a less defined structure to a special form of a digital formalized structure.

With regard to the sustainable development of a community, it seems to be important that the first batch of early adopters were making sure that it would outlast the early stages and early adopters. The increase of formal roles (e.g., formal moderators, professors), and their activities, is one aspect for such a development. So, a certain degree of formalization is a prerequisite for the future sustainability of an online community. The process of formalization in online groups is needed for successful online structures over time. To conclude, a specific degree of digital formalization might be helpful for successful communities.

However, if 'too many' formal roles emerge – more formal than informal – it might impede the continuing sustainability. Therefore, open issues are for example 'How much formalization is too much?' and 'Does *every* informal community need to go through some process of formalization if it is to sustain itself?' Further research is needed to establish if this development to more formal members is a typical one for social networking applications and 'regular' communities.

Besides these new insights, it has to be mentioned that the study reflects a special type of a community: the STC emerged 'into' or as part of an existing institution. So, the results are limited to such social institutions (e.g., universities), non-profit-organizations or companies. Communities on the Internet are often 'pure' communities without a connection to institutions ('leisure communities'). Future work should be research if our results are valid for public communities, too.

Conclusion

The analysis of the InPUD-case showed a change of social structures. We have observed that computer-supported human interactions and communication processes can lead to new rules: primarily informal structures can initiate the process of formalization. In the stages of growth, the online community formed new formal structures. For example, the InPUD-Community created new social conventions (e.g., more activities of formal moderators). Such social mechanisms affected the process of formalization. The study pointed out that the balance between formal roles at a faculty and informal activities has changed. The results indicate that the InPUD community has been formalized to a specific degree of digital formalization (please find a more detailed analysis in Jahnke, 2009).

Additionally, the study showed that more and more formal roles have been integrated into the online community. The formal structure of the mentioned faculty is on its way to a more informal structure. It seems to be that the faculty structure has been run through a process of a *de-formalization*. We need more studies to research this.

To conclude, the usage of new media with Web 2.0 characteristics can affect the balance between formal and informal social structures in organizations. Online communities – as new forms of computer-supported social interaction – establish a new combination of formal and informal structures within institutions.

However, the results presented in this paper are based on a qualitative research method called DBR. Thus, the results – about the new theory of the changing balance between informal and formal structures by new media like a STC or Web 2.0 – provide measurable variables that should be checked in a follow-up research.

Further research should focus on the question of 'Do formal structures impede socio-technical learning communities at universities, and if yes, how much? Does *every* (or just specific types of) online communities need to go through some process of formalization if it is to sustain itself?' We have to find answers to these research questions to further our understanding of such phenomena as we move from a social to a socio-technical educational system.

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A context for collaboration: Institutions and the infrastructure for learning

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Abstract: This paper discusses the role of institutional issues in the deployment of infrastructures for learning and the ways in which they can impact on the range of choices and opportunities for collaboration in university education. The paper is based on interviews with 12 key informants selected from relevant staff categories during the deployment of a new institutional infrastructure in a large UK based distance learning university. It is supplemented by participant observation by the author who was part of a group of advisors tasked with working with the project team developing and deploying the new infrastructure. The paper investigates the development and deployment of the infrastructure as a meso level phenomena and relates this feature to the discussion of emergence and supervenience as features of social interactions in education.

Introduction

This paper reports how the Open University (UK) deployed a new socio-technological platform, the Open University Virtual Learning Environment as an infrastructure to support teaching and learning. The classic conception of an infrastructure is something that is ready-to-use and completely transparent such as the electricity supply, the mail services and in more recent years the Internet. This understanding of infrastructure focuses on the objects, the elements that are built and maintained but then become relatively invisible by fading into the background. In some ways this is exactly the kind of infrastructure that is required in an educational setting, something just working, supporting learning activities and communicative practices. With the emergence of the Internet and Web it has become increasingly difficult to think of the technological infrastructure as a set of free standing artifacts because the overall form of the infrastructure and the forms of the artifacts themselves are an emergent property of social practices and technical systems. In this paper we draw on the notion of *infrastructures for learning* (Guribye, 2005) to deal with the interconnectedness of artifacts and of how in infrastructures artifacts are intermeshed with other technological, institutional and social arrangements into particular assemblages.

Edwards (2003) describes infrastructures as socio-technical systems, which though they are often viewed in terms of physical hardware are reliant on complex organizational practices both for maintenance and to make the infrastructure meaningful. Edwards also makes the point that the 'background' nature of infrastructures is in some sense definitional for an infrastructure. "Our civilizations fundamentally depend on them, yet we notice them mainly when they fail … in short, these systems have become infrastructures." (Edwards 2003 p 186). Star and Ruhleder have criticized the notion of 'sinking into the background' because they viewed infrastructure as a relational concept and did not accept the commonsense view of an infrastructure as the substrate upon which other things ran. Star & Ruhleder argue that an infrastructure occurs when the tension between local and global is resolved, when local practices are afforded by a larger-scale technology, which can then be used in a natural, ready-to-hand fashion (Star and Ruhleder 1996 p.114).

Hanseth and Lundberg examined what they called information infrastructures in the context of complex work organizations. Information infrastructures are shared as opposed to private standalone applications. They rely on standardized interfaces between components which allow the different elements to combine to provide an integrated whole. Infrastructures are open and heterogeneous in the sense that they are theoretically open to any number of users, components or computer systems linking to them and in this way infrastructural systems resemble the Internet and Web rather than closed systems. Hanseth and Lundberg go on to distinguish between work oriented infrastructures and what they term 'universal service infrastructures' intended for the use of all citizens (Hanseth and Lundberg 2001 p365). In higher education we generally deal with some kind of combination of the local infrastructures oriented specifically to learning and wider infrastructures that impact heavily on learning.

The understanding of infrastructure found in Bielaczyc (2006) and Lakkala et al (2008) takes a different stance to that found in this paper on the design of aspects of infrastructure, specifically social infrastructure (Bielaczyc 2006). Lakkala et al. take this further and add notions of technical, epistemological and cognitive infrastructures (Lakkala et al. 2008). The location of the infrastructures discussed by these authors is at a local and micro level of design. By contrast the concept if infrastructure used here is situated at the macro and meso levels in which infrastructures take the form of being given in terms of local design and not a part of the day-to-day design process (Jones et al 2006). This implies a relationship between design and learning in which infrastructures for learning aren't directly designed by the academic staff who are then involved in the more detailed pedagogic design of courses and programs.

Infrastructure, in the sense used here has been applied to learning: " An infrastructure for learning is a set of resources and arrangements – social, institutional, technical – that are designed to and / or assigned to support a learning practice." (Guribye and Lindström 2009 forthcoming). This focus on infrastructures 'designed to and/or assigned to' takes the idea of work oriented infrastructure and applies it to learning. Guribye distinguishes between the notion of work oriented infrastructure and infrastructures for learning by pointing out that infrastructures for learning do not necessarily have to be designed by the users and might commonly be designed by a variety of actors (Guribye 2005 pp 63 and 64). However we must still be cautious in the use of this revised approach because it explicitly excludes those parts of the infrastructures that are both not designed to, nor assigned to support a learning practice, but which are routinely included in learning practices.

An example are those services such as Google and Facebook which have a relationship to educational institutions and student learning practices but lie outside institutional control. One way such areas impact on institutional provision is by providing comparators for the tools supplied by the university. All universities need to consider what they need to supply in terms of their institutional infrastructure and particularly the infrastructure they provide for learning. The university cannot easily rely on external systems that depend on decisions taken elsewhere because systems can be withdrawn or they may not comply with university regulations, such as those in relation to access for students and staff with disabilities. The need for an institutional 'backbone' is related to the core function of a university which is to provide credentials and to stand behind those credentials by having warranted procedures (Brown and Duguid 2000). The university even in times of rapid technological change stands for a certain kind of institutional security.

Background to the study

The Open University VLE project, which began in 2004, aimed at the development and deployment of new tools and technologies and the integration of a range of existing tools and technologies into a recognizable and unified whole. OU courses are generally large and the university operates on an industrial scale. The university works within two main constraints, those of working at a distance and at scale. The Open University developed some of its own tools and technologies and adapted externally provided systems, such as FirstClass computer conferencing which still provides much of the online provision (for a fuller description of the OU VLE program see Weller 2007 pp 129 – 135 and Sclater 2008). The OU VLE project set out to position the OU as an innovative, high profile and high quality e-learning provider in both UK, and overseas markets. It also aimed to increase the value of the online learning experience to the learner, facilitate partnerships and enable OU staff to rapidly and efficiently deliver pedagogically appropriate e-learning that directly enhanced distance students' learning (Open University VLE Project Phase 1 Final Report December 2004).

The VLE project was developed into a coherent VLE program that began work in 2005 and a fixed term post for Director was appointed in October 2005. The aims of the OU VLE were clearly institutional in form, speaking about the university's aims and interests and positioning the University as a supplier able to 'deliver' learning processes. The OU VLE is then a good example of an institutional approach to developing an infrastructure for learning.

As part of the process of preparing for this large cross institution project an audit of current systems and projects was undertaken (Weller 2007 p131). Part of the intention behind the OU VLE project was to draw together the different strands of development, related to particular course or program needs into a more uniform approach that integrated the various elements into a single system. The original aim was to take the current systems and services and to integrate them into an open architecture based on interoperability. In the event a decision was taken during the course of the project for 'practical considerations' to adopt Moodle as a compromise between an in-house solution and a commercial solution (Weller 2007 p135).

The Research

The author of this paper was tasked to coordinate a group of academic advisors to the OU VLE program for its full duration (October 2005 – July 2008). During this period the author had regular meetings with the VLE program Director and occasional meetings with other members of the program team. The author also undertook a number of tasks related to the VLE program, including running a short course to introduce the VLE to central academic staff and evaluating a course which had been run to introduce Associate Lecturers to the VLE. The research is also based on 12 key informant interviews with Open University staff who were engaged with the VLE in a variety of roles and positions. The interviewees responses are used to examine how institutional and infrastructural issues played out during the process of the OU VLE project. The sample consisted of:

Table 1: Key informants interviews

Work location	Position	Number of interviews
University management	Senior Manager	1
VLE program	Senor Manager	2

VLE program	Business Project Leader (BPL)	3
Learning and Teaching Solutions (Media production unit)	Senior Managers	2
AACS (Computing Services)	Senior Managers	2
Institute of Educational Technology (IET)	Faculty advisors	2

The interviews were semi-structured and conversational in form and they lasted from between 30 minutes and 1 hour with the average duration being between 40 and 45 minutes. All interviews were conducted using a semi-structured interview schedule to allow comparison to be made between the different interviews, but the interviews had a conversational form and the questions only provided a general framework and not a strict guide. The interviewer had a standard list of areas to ask the interviewee about but the order of questions was flexible and the questions themselves built upon the previous comments made by the interviewee. The interviews were recorded and later transcribed before analysis. The analysis consisted of listening to the audio recordings and reading the interview transcripts to discern common themes and variations amongst the responses.

Findings

A distinctive aspect of the VLE program was the way it stood alongside but somewhat independent of the standard organizational structures of the OU.

> The management of it it's strange. There's never been anything quite like this where it's a separate organisation. I'm not saying it's not working, I'm just saying where one set of people obtaining the requirements, and then sort of having to bid against each other to get the pot of resources. (BPL)

The separation allowed the VLE program some independence of the more established units such as Learning and Teaching Solutions (LTS) the media production centre for the University or Computer Services (AACS). An important feature of the development of the OU VLE illustrated in the interviews was the temporal nature of the decision making process. What had initially been envisaged as a service oriented architecture for the new OU VLE became altered so that the Open University adopted Moodle as the basis for the new VLE. The OU like many large organizations was not in the position of developing a 'green field' site, it had to deal with the inheritance, not only of a tradition and a set of practices, such as that of 'hand crafting' each individual course's technological provision, but of having a stable and relatively successful organizational system and a set of technological solutions in place prior to the new developments.

A second feature of the temporal development was the shift from the VLE Project into the development phase of the VLE program. This was accompanied by the appointment of a temporary Director prior to the appointment of the full VLE Director for a fixed term linked to the VLE program. It was in the period when the temporary Director was in place that the shift toward the adoption of Moodle took place. Moodle was largely selected prior to the appointment of the new Director, although the final decision took place at a Steering Group in the first week after his arrival. A key figure in making this decision was another new appointment to the University. University staff who were exposed to Moodle as an alternative system were exposed to it because the University happened to appoint someone with prior experience and knowledge of Moodle. The new appointee who held a senior position in the university had installed Moodle in another university before taking up his job at the OU.

The point being made here is not critical of the process being described, it simply illustrates how contingent the decision making process was, even when the logic of the final decision was strong. Not one of the interviewees queried the decision to adopt Moodle, even though some saw strengths and weaknesses in it. However the actual decision took place in a less than systematic way. The infrastructure the OU has developed has arisen both out of a structured decision making process and the day to day contingencies of organisational life - appointments, internal politics etc. The contingent process of decision making taking place over an extended period of time can appear rational and logical on the surface but the interviews show a characteristic pattern of decision making following a logic related to immediate circumstances and unforeseen events as well as long–term planning.

At the end of the interviews the respondents were asked if there were items that hadn't been covered in the interviews that they wanted to add. The most common point that was raised was about the question of boundaries within the OU and how these either affected the VLE or were affected by the VLE program. It is clear when reading the full interviews that this was an important concern for the majority of those that were interviewed. The issue arose in two distinct forms, a concern with how existing institutional arrangements were impacting on the VLE program and secondly a concern with the ways in which the VLE program would impact on or undermine the existing divisions of labor or current institutional arrangements.

Different units or silos within the university had different standpoints and slightly different views on what was important in terms of the VLE. Two significant groupings within the Open University were Learning and Teaching Solutions (LTS) the media production centre for the University and Computer Services (AACS) which provides and supports all central IT services and it is responsible for the University's Technical Infrastructure. A sense of the way in which the tasks surrounding the VLE were perceived by LTS and AACS staff can be found in the following two quotes.

> Prior to the VLE effectively all e-learning that we did was hand-crafted, and for hand-crafted read horribly expensive… they were cripplingly expensive to produce… I think the VLE was an attempt to move away from having lots of separate systems, to having a single system or a single set of integrated systems that actually made it more straightforward to do the things that we wanted to do (LTS Manager)

> my focus is on helping to build systems to meet certain areas of functionality, and in one respect that's what the VLE is, and I guess what I'm trying to say is, I think so far we haven't actually got very far beyond where we were before we started on this process, because a lot of the functionality that currently sits within Moodle previously existed within Promises or other facilities that were made available. (AACS Manager)

The quotes illustrate that there is no single 'university' setting out requirements and the way that these divisions colored the views of what were the most significant tasks for the program. From one perspective the aim was integration with a sharp eye on costs, from the other it was the development of functionality. In many ways these two outlooks were not just divergent they were contradictory because a desire for integration and reduced costs meant that at times compromises had to be made in terms of the development of functionality.

The introduction of the OU VLE has had a recognized impact on the existing division of labor within units and the division of work and responsibility between units in the University. One way in which this was described in the interviews was in the way the new technology suggested that the current pattern of production and presentation might be disrupted. The effects of the change in technologies could have significant impacts on the process of work and the flow of work through the institution. The current division of labor envisages a relatively clean break between course production and presentation, yet the technology enables and may even encourage the reconnection of these two activities.

Discussion and Conclusions

Path dependency has recently been defined as "the "lock-in" effects of choices among competing technologies." (Edwards et al. 2007 p17). Edwards goes on to identify social investment (e.g. time to train), positive network effects and individual habits and organizational routines as providing resistance to change. There are a number of points in the interviews when path dependent effects can be identified. In the way that an earlier conferencing FirstClass remains in use and colors the use and appreciation of Forums in the Moodle based OU VLE. In the way that previous tools developed in house set levels of expectation about the new tools in the VLE. In the way that decisions taken at particular points in the process of the VLE project and program had impacts that 'locked-in' later outcomes. There is nothing new or necessarily negative about path dependency, indeed positive path dependency occurs when effective new practices build on and emerge from old practices. Path dependency is however an issue that needs to be explicitly addressed in infrastructure development processes such as the OU VLE.

The literature in CSCL has seen a development of concerns with larger scale phenomena and a move away from a simple focus on small scale group settings (see for example the proceedings of CSCL 2007 e.g. Kapur et al.). It is tempting in this context to deploy the idea of emergence as an explanatory tool for understanding a range of issues. Often the form of the argument about emergence takes the form of individual agent and collective system.

> The concept of emergent behavior is, however, rather paradoxical. On the one hand, it arises from the interaractions between agents in a system, e.g., individuals in a collective. On the other hand, it constrains subsequent interactions between agents … It becomes fundamentally important to understand *how* macro-level behaviors emerge from and constrain micro-level interactions of individual agents. (Kapur et.al. 2007)

The research presented in this paper fundamentally questions this position by suggesting that agents are not simply individuals but are often acting in roles assigned by their positions in an historical and ongoing pattern of events. Arguably this is a standard sociological understanding that is particularly applicable in education. Patterns of emergence in such contexts take place mediated by emergent forms that already have a long history and that can supervene in the interactions between agents, having a causal role independent of the individual agents identified above.

The evidence of path dependency shows how agents in universities are positioned within a field of interaction with a distinct temporal dimension. The reflexive development of software systems shows how the software carries with it earlier histories of its development (in this case Moodle was a course based system), but it also demonstrates how the developers in a university can amend and vary the characteristics of the software to incorporate new features and different metaphors for teaching and learning (such as an organization around programs or persons rather than courses). All of these features point to a need to understand meso level factors that stand somewhere between top down and bottom up processes. In part the evidence presented here can be seen as suggesting a need to understand the missing middle in CSCL.

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Main functionalities of the Knowledge Practices Environment (KPE) affording knowledge creation practices in education

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Abstract: The present paper examines how to develop technology-mediated educational practices from acquisition and participation type approaches towards more sustained, collaborative knowledge creation, where students' work is organized around developing shared epistemic objects (artefacts, processes, practices). Typical forms of technology-mediated collaborative practices in education are illustrated through a framework of 'stairs of collaboration' related to three metaphors of learning: knowledge acquisition, participation and knowledge creation. It is maintained that typical functionalities in existing educational web-technologies, such as various Virtual Learning Environments (VLEs), are quite inflexible and inadequate for shared work on epistemic objects. The main focus in the present paper is on describing how a basic platform supporting collaborative knowledge creation, called Knowledge Practices Environment (KPE), has been built to provide affordances to work around epistemic objects and practices.

Introduction

A current challenge for education is to prepare learners for the emergent knowledge society through appropriate pedagogical practices that promote competencies for sharing, creating and working with knowledge and knowledge artefacts in an innovative way; such work would necessarily involve planning related processes together. Pedagogical practices that are considered to help to improve such competences include features such as student ownership and active involvement; collaboration between participants; activities of searching, sharing and elaborating knowledge; working with authentic, ill-defined problems; and critical reflection on one's own activity (Ilomäki, Lakkala & Paavola, 2006; Kozma, 2003; Scardamalia & Bereiter, 2003). Knorr-Cetina (2001) used the notion of 'epistemic practices' to describe such knowledge-centered activities in education and work contexts. We use the term 'knowledge practices' as a near synonym for this.

Theoretical approaches emphasizing learning activities where people are collaboratively developing new artefacts and systematically transforming their knowledge practices relate to the knowledge creation metaphor of learning (Hakkarainen et al., 2004; Paavola & Hakkarainen, 2005). The notion builds on the two metaphors of learning – the knowledge acquisition metaphor and the participation metaphor – introduced by Sfard (1998). *Knowledge creation metaphor* refers to various theories that aim at understanding how to organize long-term collaboration to simultaneously develop new knowledge and related processes. We maintain that these theories, in spite of their differences, emphasize the role of *mediation* and the *object-oriented nature* of human activity, as do the knowledge building approach (Bereiter, 2002), the progressive inquiry model (Muukkonen et al., 2005), and the theory of expansive learning (Engeström, 1987). We call this approach '*trialogical*' (Paavola & Hakkarainen, 2005; Paavola & Hakkarainen, in press) and differentiate it from those models of learning that emphasize processes within the human mind ('monological' relating to knowledge acquisition metaphor), and from those approaches emphasizing social practices or interaction ('dialogical' relating to participation metaphor). The trialogical approach develops models and tools for organizing learners' activities around shared 'objects' (such as texts, models, conceptual artefacts, but also practices) that are created for some real purpose or subsequent use, which is often not the case in conventional educational practices. Within the trialogical approach, individually performed activities and social interaction serve the longer-term processes of developing specific, concrete, shared objects, collaboratively. Shared epistemic objects and practices are not fixed objects with stable properties like materials typically used in educational settings, but open-ended, future oriented, and in the process of being defined by the participants (see Knorr-Cetina, 2001).

Modern information and communication technology (ICT) presents new opportunities, yet also new challenges for education. Technology enables new ways of collaboratively working with knowledge, but these possibilities also raise the question, How should technology best be implemented to serve these educational practices. Computer based media have, for a long time, been seen to support either "*the information genre*" or "*the communication genre*" in people's activities (Enyedy and Hoadley 2006); that is, existing ICT is mainly suited for sharing information ("monologues") or for supporting social interaction ("dialogues") as respective social activity. Web-based technology, however, gives new means for collaboratively developing and creating epistemic artefacts and related practices (Miettinen, 2006). Some recently developed network applications, such as wikis, have been especially designed to afford this kind of co-construction of knowledge through the Web. Consequently, modern technology is closely related to practices of working with knowledge, but also to specific ways of understanding learning; these ways are similar to the knowledge creation or trialogical view.

In the present article, we first suggest a framework that shows, concretely how various types of technology-mediated collaboration in typical educational practices can be outlined in relation to the three metaphors of learning. Then we describe how the ideas of relevant software support for collaborative knowledge creation have been implemented in a Knowledge Practices Environment (KPE), a web-based system developed in an EU funded Knowledge Practices Laboratory (KP-Lab) project (see http://www.kp-lab.org).

Forms of collaboration through technology

If it is acknowledged that one central goal in present-day education is to transform technology-mediated practices from acquisition and participation type approaches towards systematic knowledge creation practices, then the desired transformations have to be explicated in more concrete terms. For instance, what is the relevant nature of students' activities or the role and type of appropriate technology, compared to existing conventions and technologies. In the present article, we have modeled the varying forms of web-based collaboration practices by illustrating them in terms of 'the stairs of collaboration' (see Figure 1), building on the ideas of Lehto and Terva (2001). The steps in the framework are defined according to the increasing extent and complexity of collaboration that the practices reflect and the changing role of knowledge and technology in the process. The framework aims at defining various forms of collaboration in a practical way. Note: The same technologies can be used is many ways; 'typical technology used' does not imply a deterministic relationship between the technology and level of practice but suggests 'prototypical' practice. Naturally, frameworks of this kind are always simplifications, but the purpose is to provide new conceptual means for analyzing basic forms of knowledge practices and relevant features of supporting technology.

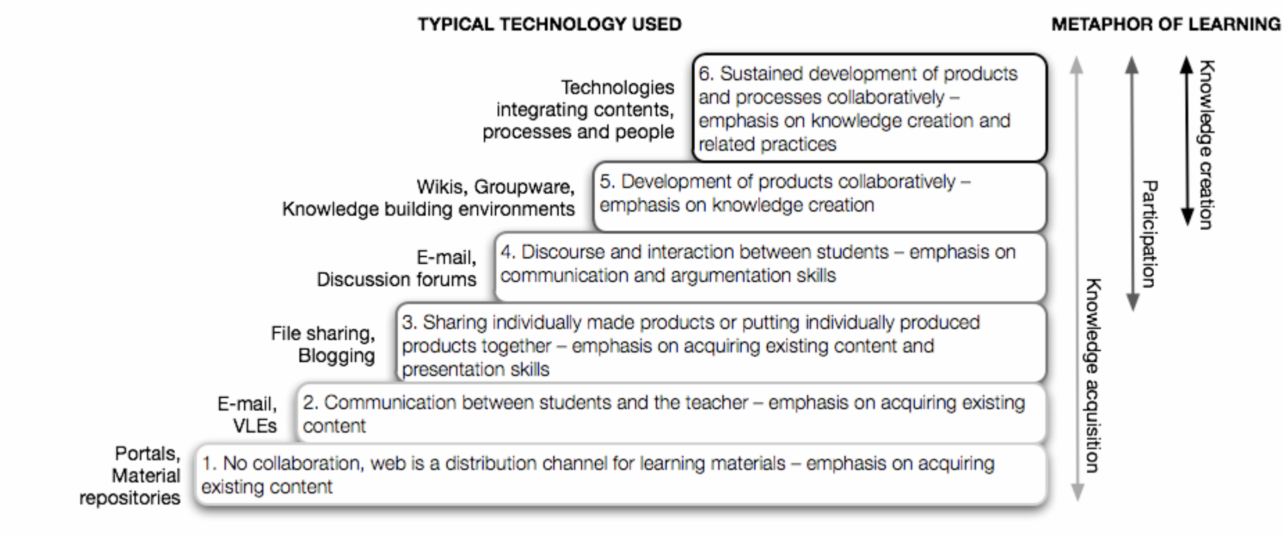

Figure 1. Stairs of web-based collaboration practices in education.

The lowest step in Figure 1 represents practices where the network serves as a transmission channel of educational materials without any communication between actors; for example self-study tutorials made available through a portal in the Internet. On the second step, the interaction occurs only between the teacher and the students; students are not at all in contact with each other. This kind of practice is actualized, for example, in educational units where students submit their task accomplishments to the teacher through some VLE, and the teacher sends individual feedback for each student through e-mail. Usually, individual learning and adoption of certain contents is emphasized in both forms of practices.

In the practices described from the third step upwards, students are also in direct interaction with each other. Typical practices representing the third step are, for example, assignments where the students first prepare written material about some topic individually, and then share the outcomes for all to read through some file-sharing system. Students might also write some comments to each others' work afterwards without actually interacting with each other or without revising their texts according to the feedback. The creation of material during the course can itself be a very demanding task for the students, but actual collaboration between the students remains minor, if the outcomes are distributed only for reading.

The fourth step describes practices where students are directly and reciprocally interacting and communicating with each other. It has been a very popular way in various educational settings to use web-based technology for assigning students to discuss, within that environment, various themes relating to the course topic through 'discussion forums' (Dysthe, 2002; Schrire, 2004). The organization of discussions can be quite loose, or alternatively more structured according to some sub-themes or communication and argumentation principles (Andriessen, 2006). Often the primary objective in such activities is to let students practice communication or argumentation skills; these include presenting and defending one's own opinions, accepting different viewpoints or constructively arguing and commenting on each others' ideas. Naturally, students are also expected to learn something about the topics that are the object of discussion.

The most challenging type of collaborative work occurs, in the fifth and sixth steps, when collaborators attempt to produce and modify concrete products or outcomes as the result of shared efforts; all members are assumed to participate in and take responsibility of commenting, planning, revising and developing common sketches and versions of the products. The outcome of such activity can be, for example, a common written report on a chosen subject, a design product, or a solution to an open problem that is framed together. The fifth step in Figure 1 refers to such activities where students' working is directed to the development of some epistemic objects. In the sixth step, the collaborative process, the way of working itself, in addition to the shared knowledge objects, is also subject to joint reflection and development. In such practices, students are assumed to learn the multidisciplinary content, practice communication and interaction skills; in general, they are to develop competencies and metaskills for collaborative knowledge creation in an integrated manner.

Mediating role of technology in knowledge-creation practices

The multifaceted role of technology in enhancing knowledge-creation practices can theoretically be modeled through different *types of mediation*. In the present article, technological design solutions are described and clustered under the following mediation types (we reformulate the types of mediation introduced by Rabardel and Bourmaud, 2003; see also Hakkarainen, 2008):

- *Epistemic mediation*: creating, transforming, organizing and linking knowledge artefacts;
- *Pragmatic mediation*: planning, organizing and coordinating working processes;
- *Social mediation*: managing social relations around shared objects and linking people; and
- *Reflective mediation*: making visible and reflecting on the work processes.

We maintain that currently available tools (such as e-mail or file sharing systems) or VLEs (BSCW, Moodle or Blackboard) provide only limited support for collaborative knowledge creation because they typically provide functionalities only for information sharing and participation in social communication. In existing VLEs, epistemic objects often remain static and isolated, without possibilities for users to explicate relationships between them, rearrange them or build on them over a longer term. There are few existing educational applications that are generally targeted for knowledge creation. Most well known is Knowledge Forum (KF), developed for knowledge building practices (Scardamalia & Bereiter, 2003). KF has inspired the development of KPE because it provides a knowledge space with many functionalities to create, link and build on shared multimedia objects. Another system, FLE3, was developed for progressive inquiry practices (Muukkonen, Hakkarainen & Lakkala, 1999; Leinonen, Kligyte, Toikkanen, Pietarila, & Dean, 2003). It includes tools supporting virtual inquiry discourse as well as the sharing, co-construction and versioning of digital artefacts. Both systems emphasize issues within epistemic mediation. Usually the tools do not include functionalities for planning and coordinating processes or integrating people, contents, and processes in a flexible and transparent way. In a review concerning new Collaborative Environments (CE), the New Working Environments Unit of the Directorate General Information Society and Media of the European commission summarized in its report,

> the characteristic of current CE is that they are not integrated and inter-operational, that they support mainly point to point and not multipoint conferencing, that they are defined mainly for structured environment providing static artefacts and that they do not support the unstructured orchestration of activities using collaboration aware objects. Finally they focus primarily on peer communication and not flexible team interaction. (New Collaborative Working Environments 2020, 2008, p. 10)

The emerging tools based on Web 2.0 and semantic web technologies address the above challenges of collaborative environments. While many outstanding tools are already available, they are not easily usable in an integrated manner by learners and educators who do not have enough resources or competencies to appropriate the possibilities of these diverging tools for their needs. Due to poor interoperability, integrating state-of-art tools is also technically difficult and often requires software re-engineering, which in turn makes maintenance of the systems more difficult.

Features in KPE to provide affordances for collaborative knowledge creation

In this section, we describe a web-based application, Knowledge Practices Environment (KPE), which is designed to provide specific affordances for joint development of concrete, epistemic objects as well as for planning, organizing and reflecting on related tasks and user networks (see Markkanen et al., 2008). With KPE, users are able to build collaboration environments by creating and configuring the means, as opposed to operating in predefined structures, of the common practice. KPE is a virtual environment that includes a set of basic, integrated tools (e.g., working spaces with real-time and history-based awareness, wiki, note editor, commenting, chat, semantic tagging and semantic search) for working with the shared knowledge objects.

KPE enables object-bound and threaded commenting on all items (task items, files, web-links, notes) in a shared space, as well as viewing of knowledge objects and their relations from several perspectives. Three basic perspectives are content, process and community views. Various tools and functionalities are highly integrated in the basic views to enable versatile and flexible connection, organization and reflection on all information related to the knowledge objects, processes and people concerned. Below, the basic functionalities of KPE that provide affordances for collaborative knowledge creation practices are described, in clusters according to the envisioned types of mediation. Some screen shots that are presented to exemplify the software are picked from real course settings. Some features were not yet tested in authentic settings because of their impending release only in autumn 2008; therefore, an illustration of possible usage is built into the figures.

Work with knowledge artefacts

Epistemic mediation is supported in KPE by functionalities that enable users to create, modify and organize various knowledge artefacts as well as their relations, in versatile ways. Below, some central characteristics related to the work with knowledge artefacts are briefly described.

Sharing and co-construction of knowledge artefacts with free visual arrangement and linking

In KPE, user groups can create 'Shared spaces' through which various knowledge artefacts can be shared and co-constructed. Like in any VLE, users can upload any type of files or web-links into shared spaces. But instead of providing only a space to store and manage vast number of documents, KPE enables the users to organize knowledge objects (represented by graphical icons) through flexible, visual representations. A central view in KPE for working on knowledge artefacts is the *Content view* that allows free visual arrangement and linking of its content (see Figure 2). KPE is not based on folder structures or hierarchical presentation of the content; it does not hide the content into folders, which detach items from their relations. Visual organization is supported by various mechanisms, such as spatial arrangement and linking of items, filtering of items based on metadata and tags, the creation of user defined views ("tailored views") as well as the creation of visual models on top of existing views.

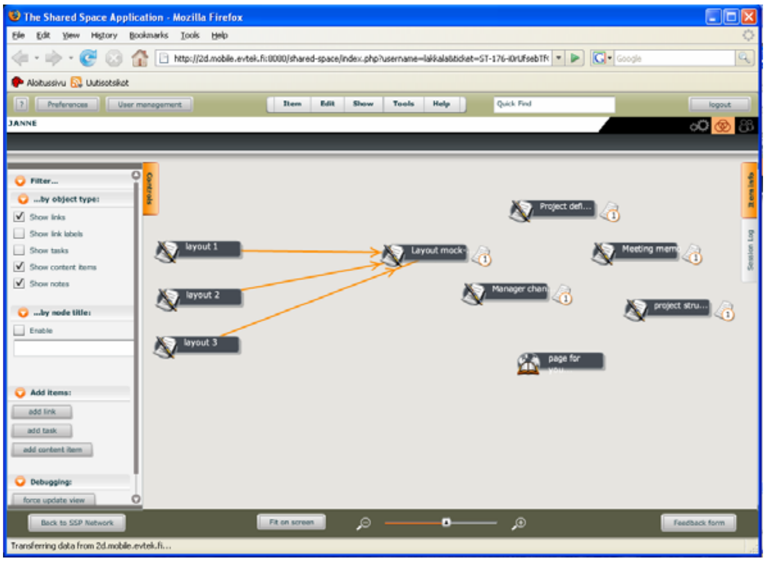

Figure 2. Visual arrangement of content items in one student team from a design course in Media Education in Metropolia University of Applied Sciences, Finland.

In addition to a possibility to upload files in a Content view, some specific tools are built in or integrated in KPE to support easy production of texts and sketches as well as co-editing and comparison of text versions. With *Note editor,* users can directly write their ideas and thoughts as content items in a shared space, without the labor of creating and uploading an external text file (Furnadziev, Tchoumatchenko, Vasileva, &

Lakkala, in press). All members of a space can open and edit the created notes and view their previous versions. Furthermore, users can open many notes simultaneously for comparison and integration, and link notes to other content items in the Content view (see Figure 3). The implementation of Note editor in KPE is a simple but powerful tool for collaborative knowledge creation; it draws on the idea in Knowledge Forum (Scardamalia & Bereiter, 1994), that to foster knowledge building, one proceeds through idea generation and elaboration using textual notes. The Content view also includes a *Sketch pad* tool that is based on the same idea as Note editor, but which enables creation, co-editing and versioning of simple drawings and visual sketches. In addition, KPE affords groups the ability to write collaboratively in an integrated wiki. A wiki document can be created as a content item in the Content item view, which offers the possibility to access the same wiki document from a shared space. The progress and changes made to the document are visible to all group members.

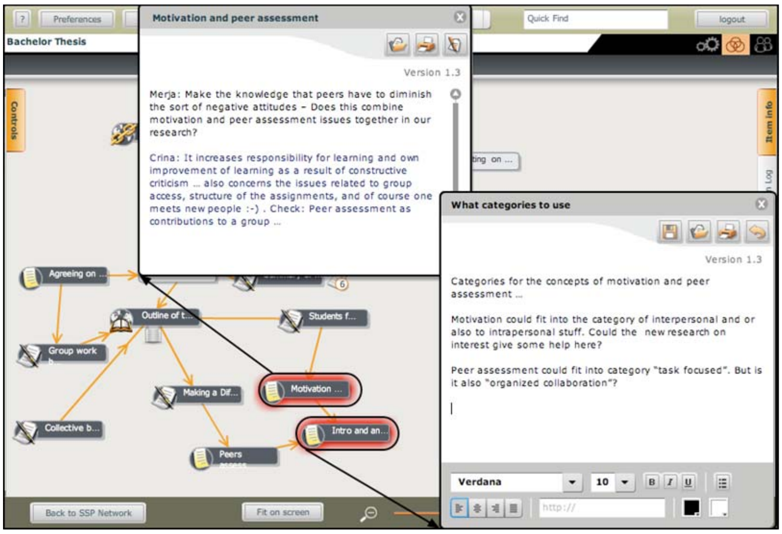

Figure 3. Illustration of Note editor with two notes opened simultaneously.

"Object-bound" interaction around knowledge artefacts

In the Content view, object-oriented collaboration is emphasized by content-bound commenting functionality (see Figure 4) that allows asynchronous, threaded discussions attached directly to knowledge objects. One object can have many comment threads, thus enabling users to discuss various aspects of the objects, directly, in context. This object-oriented aspect places KPE beyond isolated discussion forums, threaded notes or argumentative discussion supports, which concentrate on the dialogical aspect of collaboration and so lose the context; KPE answers the need to have individual contributions attached in collaborative work that is organized around shared knowledge objects embedded and embodied in a shared space. Similarly, object-bound chat enables synchronous interchange attached directly in the content items at hand. Chat log is saved and linked to the targeted content item, therefore keeping the log attached to its object for possible re-use and continuation.

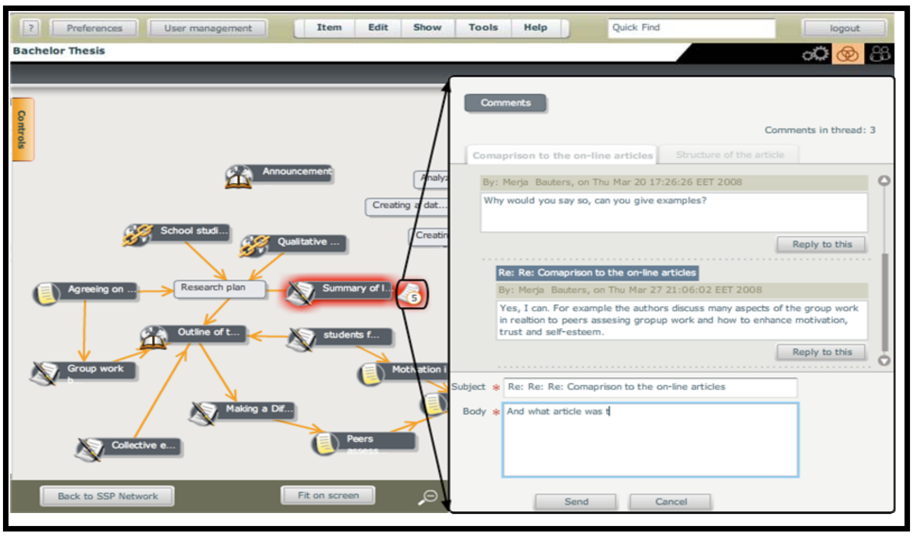

Figure 4. Illustration of content-bound commenting

Flexible use of metadata, tags and ontologies

One aspect of KPE that goes beyond current learning environments is the use of metadata and semantic features to support the usage and integration of knowledge artefacts in various ways. Tags and tag vocabularies can be created and edited by participants, or be taken from ready-made vocabularies. In the Content view, all items can be tagged. This provides additional affordances for various types of knowledge practices in education, as compared to existing tools. For example, in typical research seminars, semantic tagging can be used to help students find common areas of interest and related materials or to analyze the elements and concepts of existing and produced research papers. In addition, the tags or concepts that users define are implemented in the underlying technology in a way that allows search through the semantics or relations between tags; e.g., semantic information can be reused across various integrated tools. Such functionalities allow the users to create their own cognitive and conceptual tools and instruments based on the potentialities of the semantic web.

Organizing processes

Pragmatic mediation has been central in the design of the functionalities of KPE for planning, monitoring, and regulating joint activities and working processes. These functionalities enable users to define tasks, draft visual representations of processes, as well as they provide users with ‘awareness features’ (see below) of the activities in the spaces.

Process planning through defining tasks and drafting visual process representations

In addition to content items, in KPE, users can explicitly define, modify and arrange *task items* to fit their process and domain, including, e.g., descriptors of title, responsible users, start and end dates, and status. This feature allows users to explicate their process elements and promotes responsibility and ownership over their decisions and actions. In the Content view, task items can be presented, linked and arranged in the same visual representation together with the content items, which provides users with a holistic view of their knowledge creation processes, without separating tasks from contents (see the left screen shot in Figure 5). Spatial representation and emphasis on relationships between tasks as well as tasks and contents is especially useful in educational settings, where the chronology of the work is not essential, but there is a requirement to see connections, associations and causal relations between the various elements of the process.

The same tasks that are displayed in the Content view with their relations to content items can be viewed in *Process view*, presently in the form of a GANTT chart (see the right screen shot in Figure 5). The Process view enables users to plan tasks and processes in a chronological manner as well as to monitor how the required tasks have been accomplished. For instance, in courses that teach collaborative design practices, where real design projects are executed, it is highly important (for flexible adjustment of the process) that participants be able to monitor the progression of the project and modify the tasks. Again, interdependencies and mutual connections between the tasks defined in the Process view are in turn automatically converted by the system into graphical constructions representing these connections in the Content view.

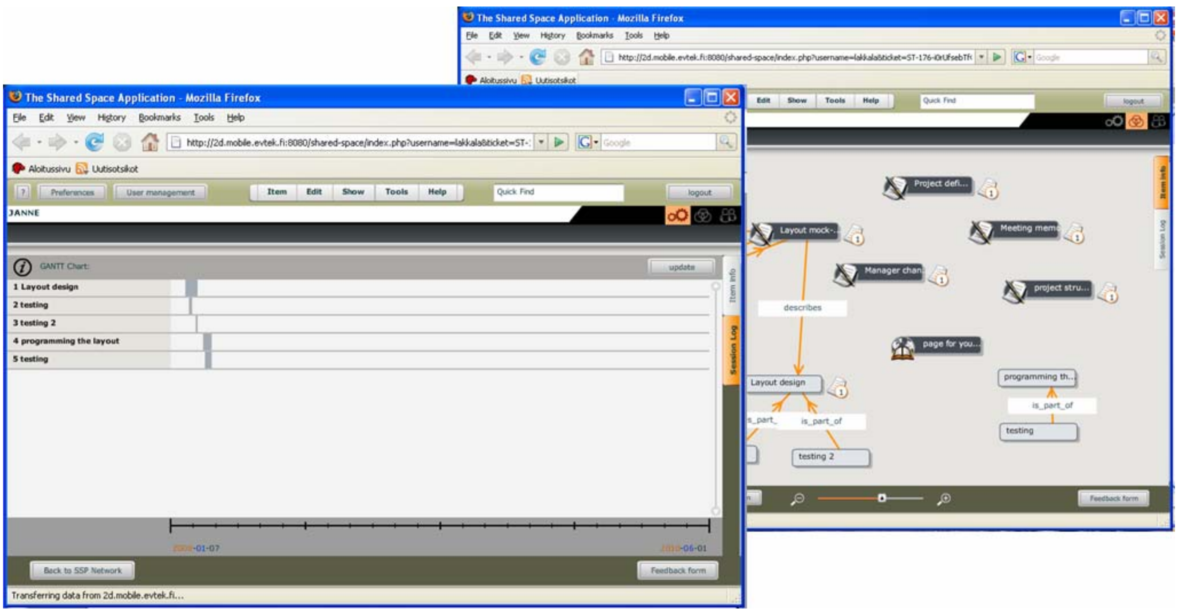

Figure 5. Right: Spatial arrangement of knowledge artefacts in the Content view including content items (black), tasks (grey) and labeled relations. Left: The Process view presenting the same tasks in a GANTT chart.

Features for focussed work on particular knowledge objects and tasks

The management of knowledge creation processes is further supported in KPE by the use of *tailored views*, into which the users can transfer selected parts of the process (tasks and content items, links, etc.) from the Content view to work within a particular theme or phase of the process in a focused manner. Tailored views provide another visual means to organize knowledge creation processes by enabling users to arrange shared knowledge objects according to a background image or visual structure that presents the different parts of the process (e.g., certain phases in a pedagogical approach used). Tailored views support processes in which a particular topic requires deepened focus, without the abundance of all the material (e.g., inquiry-type practices) or where particular phases need to be conducted separately in order to be able to move to the next phase (e.g., project based practices).

Awareness features to aid process planning and coordination

Planning and coordination of a collaborative working process, be it asynchronous or synchronous, will highly benefit from *awareness features* that help in explicating tacit knowledge related to one's own or others' working practices. Often awareness features are not consciously noticed or paid attention to; however, they may play an essential role in tool-mediated collaboration, keeping track of on-going and past actions. Without such information, the work may be severely hindered. Awareness features in KPE are meant to support synchronous work are, for example, visual clues and on-line notifications about who is online, who is working with whom, or who is working on what object and how (see Figure 6). Historical perspective is provided, e.g., by a list about modifications of knowledge objects and tasks or by e-mail or mobile device notifications about the events in a shared space.

Social relations around shared objects and processes

In KPE, social mediation is envisioned in functionalities that support users in maintaining their contacts and keeping up with changing information about other participants, as well as their relations to the shared processes and content items. Social mediation provided by the tools allows users to lean on each others' competencies, expertise and experience and help them align their thoughts and actions with those of others.

Organizing social structures, responsibilities and roles

For the smooth coordination of collaborative work, it is crucial to explicitly define the social structures among the participants, such as groupings, responsibilities and roles. To begin with, for each content or task item visible in the Content or Process views, it is possible to define persons responsible for that item. In addition, a third basic view of KPE, called the *Community view* (see Figure 6), is especially meant to support the coordination of tasks and responsibilities between participants. It presents a list of users with indications who is on-line. Detailed user information includes a list of all tasks and knowledge objects that have been created and modified by or assigned to a particular member. The awareness features mentioned above include clues and notifications of each user's status as well as past and present activities. The flexibility of social structures is increased by allowing users to define various roles and access rights to participants, in order to alter the prominent practice, in many virtual learning environments, of predefining fixed teacher and student roles.

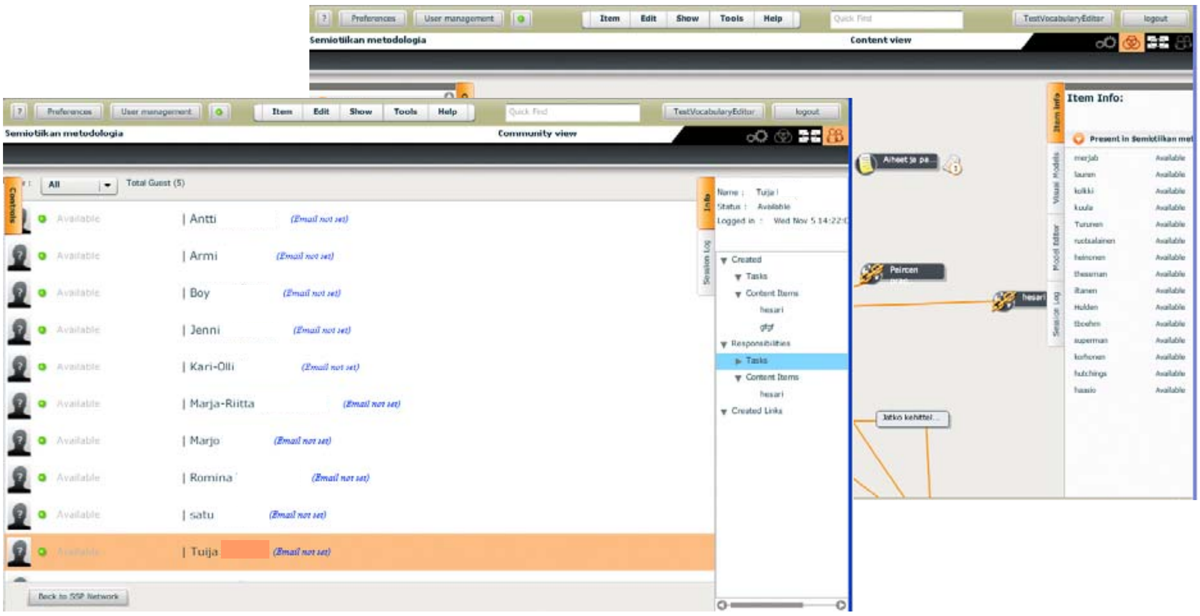

Figure 6. Left: The Community view. Right: Information about on-line users in the Content view.

Integrated communication means and social clues

As mentioned above in relation to epistemic and pragmatic mediation, KPE offers means to keep in contact with others, such are asynchronous commenting possibilities, or general chat and context bound chat to enable synchronous discussions. Awareness features include clues and notifications of participants' status or past and present activities. In addition, the integrated Meeting Management tool (M2T) enables creation and preplanning of meetings as well as formulation of meeting templates for further use. All these tools are meant to support the planning and organization of ongoing activities in an integrated way, not only from each participant's private perspective, the latter being the dominant manner we have observed in current, virtual learning environments.

Reflecting on processes for deliberate transformation of knowledge practices

The last of the four types of mediation enables actors to reflect on and evaluate their joint activities as well as the shared objects being created and modified collaboratively. The aim is to provide user groups with information that allows them to take the community's knowledge creation processes as an explicit object of shared reflective activity and, consequently, elicit deliberate transformation and improvement of their joint knowledge practices. The reflection is afforded in KPE in many ways by the above mentioned and additional functionalities (e.g., visual representations, awareness tools or analytical services).

Reflecting on the on-going processes through visual representations and awareness tools

One virtue of the visual representations of content items (and related processes) is that they provide users an overall, graphically supported overview of current state of the shared space for the critical evaluation of the process. In addition, the various awareness functionalities, mentioned above, enable users to keep track of the process progress and perceive what is going on with the shared objects and tasks, see what the others are up to, but also acquire off-line information about events and on-going activities.

Reflection and analysis of past processes through analytical services

Various analytical services in KPE will provide users with possibilities to reflect on the process from a historical perspective. Especially for researchers and teachers, KPE provides functionalities for exporting the available data from a knowledge repository, covering all changes made in the selected part of the knowledge practices environment for a specified period of time (*Data export tool*) and use external data analysis tools to evaluate the data. One means to monitor what is going on within the working environment and to reflect on the community's practices will be *knowledge evolution analysis* that gives information about the evolution of contents and work processes. Methods of social network analysis are utilized for presenting and visualizing various social processes that emerge between people as well as people and artefacts through KPE.

Results from field trials piloting KPE in educational settings

In the spring and autumn terms in 2008, a few pilot studies were conducted in the University of Helsinki and in the Metropolia University of Applied Sciences to examine the utility of test releases of KPE in authentic course settings. Below, some results from two experiments are briefly reviewed. Note that the technology was still under development during the time of studies; therefore the experiences and results are mainly indicative.

In Metropolia, KPE was used by second year Media Engineering students in a term project, through which they are expected to improve their practices in managing projects and dealing with real situations, while designing a product or service for a real client. The functionalities of the Content view and the Process view were in use for mediating the collaborative creation of design artefacts (epistemic mediation) as well as process planning and coordination (pragmatic mediation). According to the analysis of student teams' shared spaces in KPE (see also Jalonen, Kosonen & Lakkala, in press), the possibility for visual mapping of shared knowledge objects was used for explicating the structure and logic of the teams' design process. Students reported that the visual, open and easily modifiable Content view helped the sharing and versioning of documents as well as organizing and getting an overview of the process. There was also challenges because the changes made to the shared view required explicit coordination and mutual decisions between the team members. According to one interviewed student team leader, the current version of the GANTT chart in the Process view was usable for general planning of the design project, but it lacked many functionalities that are central in process planning, such as more informative timeline or a possibility to define dates in the more detailed level. In general, student teams appeared to resort to a fairly strict division of labor when organizing their team work, instead of collaboratively working on their design documents.

In the University of Helsinki, KPE was used in a bachelor year methodology course on semiotic studies. In the course, students wrote scientific reports in pairs. The Note editor, commenting functionality and tailored views were suggested to be used for co-constructing questions, ideas and versions of the report. According to the observations, the use of Note editor to formulate questions and to comment on others' questions did aid the students to grasp the relevance of generating research questions. In the course feedback, the students mentioned that they considered the functionalities to be useful for their inquiry task. The linking was reported to be used for two purposes: to visually organize artefacts in the Content View and to define which artefacts were based on which artefacts; i.e., explicate the evolution of artefacts. One intriguing notion is that, from observations, it appeared that the students were not using the linking much, but in the course feedback, linking was mentioned as important. Tailored views were not used as much as was envisioned, since it appeared to be hard for the users to operate with them. The visibility of all artefacts in the Content View was considered good for sharing artefacts, but also confusing. The search and recent changes functionalities were still lacking from KPE during the course, which apparently caused a feeling of confusion about managing all artefacts. The students pointed out that they missed the search and recent changes functionalities to 'know what has appeared in the space since last time'. The possibility of having synchronous chat sessions integrated with the shared space (see Furnadziev, Tchoumatchenko, Vasileva, Lakkala & Bauters, in press) was appreciated for keeping contacts with other students of the course, and with the partner writing the same report; however, not all students found the chat tool. Furthermore, clearer guidelines were asked by the students for the usage of KPE. In general, it appears that the students were positively surprised about the amount of comments and feedback they received through KPE during the process of writing their report. We may conclude that the Note editor, commenting and linking functionalities both helped to organize the artefacts (epistemic mediation) and promoted reflection (reflective mediation). In addition, it could be stated that the possibility to keep contact by integrated chat was important, especially in this kind of course, where the students come from various disciplines and the course meetings are the only possibility to meet each other face-to-face (social mediation).

Discussion

The functionalities of the Knowledge Practices Environment, described in the present article, are developed in co-design processes integrating theoretical ideas, pedagogical research and technological development, based both on the viewpoints of the "trialogical" approach to learning, and previous research and experiences with existing tools. The functionalities were described by structuring them according to the theoretically motivated *types of mediation.* Much of the added value of KPE is the high integration of various functionalities to build an integrated and flexible virtual collaboration environment to provide *multimediation* for various uses. The purpose of the combination of these functionalities is to allow users to be engaged in sustained collaborative processes for creating knowledge items or models, as well as for planning and reflecting on their practices.

The Knowledge Practices Environment as a context for collaborative knowledge-intensive working processes is based on the notion that knowing and learning in the complex contemporary world largely rely on collaborative creation, evaluation, modification, and implementation of resources, practices and representations. With KPE, user groups can implement and customize available tools and resources for their own purposes. Epistemic and pragmatic mediation embedded in the KPE enable the integration of users' collaborative and individual efforts in creating material artefacts and coordinating their activities. Social mediation, provided by some functionalities, allows users to lean on each others' competencies, expertise and experience and helps them align their thoughts and actions with those of others. Reflective mediation is afforded by various means for viewing and monitoring the transformation of knowledge content, activities and social relations.

KPE is a part of a larger, integrated *KP-Lab system*, developed in the KP-Lab project for five years (2006-2011); this paper only provides a snapshot of the achievements so far. The KP-Lab system is ontology driven and provides a platform to develop advanced semantic tools for collaborative learning. The first prototypes of a semantic multimedia annotation tool and an editor for visual models and visual modeling languages (used for collaborative semantic modeling) are released for field trials. All KP-Lab tools are based on a foundational data model that provides common semantics for the tools and platform services. It is extended by the tool ontologies in order to describe the more specific semantics required.

In addition to on-going technical development, a necessary next step in the KP-Lab project will be the testing of the utility of the tools and developing pedagogical models, widely, in various educational and workplace settings. The true affordances of the designed tools and functionalities for mediating real knowledge practices and their development can be evaluated only when the fully functional tools are available throughout the real knowledge creation process.

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Testing and Validating Frames for Online Organizations

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Abstract: In this paper we suggest that online environments can function as alternate "organizations" for pre-service and beginning teachers who may find themselves struggling in schools. Building on prior work on framing and reframing in organizations and schools, the authors present a new frame of analysis specifically geared for web-based learning/support communities. Data consist of transcripts from three forms of online discourse—an e-mail listserv, an electronic discussion board, and a course-related wiki—from three groups of pre-service secondary teachers (grades 6-12) located in three U.S. states. The development and testing of the new frame and its potential use is relevant for teachers, teacher educators, and school administrators.

Introduction

There are many unanswered questions concerning teacher perceptions of school culture and support as it affects self-efficacy (Tobin, Muller, & Turner, 2006). Turning to the fields of sociology, organizational learning, and framing may yield some answers. In particular, applying the research on frames and reframing may help us understand the complex relationship among teachers, climate, and the organization of schools. In this paper, we explore the notion of frames and reframing (Achinstein & Barrett, 2004; Benford & Snow, 2000; Bolman & Deal 1994, 1997; Schön, 1987) to investigate how online networks function similarly and/or dissimilarly to physical organizations. More pointedly we ask: How can prior work on frames and reframing be applied to online support communities? This paper opens with the foundational literature pertinent to beginning teachers, support mechanisms, and notions of framing and reframing. The authors next describe the methods employed to create a system of frames (Scherff & Singer, 2008) for online organizations and provide a brief summary of preliminary findings.

Supporting Novice Teachers through CMC

A common challenge facing pre-service teachers is reconciling the pedagogy they are learning in their university coursework with the day-to-day reality of schooling. Veenman (1984) terms this praxis shock. To combat praxis shock, beginning teachers need both instructional (planning, assessing, managing the classroom, etc.) and psychological (efficacy, stress management, etc.) support (Gold, 1996; Veenman, 1984). One approach to provide instructional and psychological support is through computer-mediated communication (CMC) tools. Because CMC can occur at nearly any time or place, it provides more options for peer support not always cultivated in schools or classrooms (Scherff & Paulus, 2006). Research shows that online support networks provide beginning teachers with "social, emotional, practical, and professional support" (DeWert, Babinski, & Jones, 2003, p. 319), moral support (Merseth, 1990), a space to make connections (Romiszowski & Ravitz, 1997), deeper conceptions of teaching and learning (Ferdig & Roehler, 2003-2004), and practice with collaborative reflection (Nicholson & Bond, 2003). CMC provides additional time to reflect, craft a statement, and respond to others. Via CMC, novice teachers write for an authentic audience about real classroom issues. Moreover, CMC can be better than face-to-face conversations since it provides an instant audience at any time and in any location (Scherff & Singer, 2008). However, there are some drawbacks to using CMC. For example, CMC tools provide few visual or intonation cues (Ferdig & Roehler, 2003-2004), which can make it difficult to establish trust or a sense of community in online learning environments, particularly for novice users.

Frames and Reframing

Crossing the fields of psychology, sociology, linguistics and discourse analysis, and policy studies, frames are how we see things in and make sense of our lives; frames also help us set boundaries, identify problems, form opinions, and discover solutions (Benford & Snow, 2000; Entman, 1993; Goffman, 1974; Judge, 1992). Schön (1983) found that teachers frame difficult situations that surface in their practice through "naming the problem, setting boundaries of attention to it, and imposing coherence to provide directions for change" (cited in Achinstein & Barrett, 2004, p. 719). When faced with a new problem or challenge, reflective practitioners reference their experience with comparable past problems and then amend their current practice correspondingly. Frames are also used collectively, "developed, generated, and elaborated on . . . through three sets of overlapping processes that can be conceptualized as discursive, strategic, and contested" (Benford & Snow, 2000, p. 623). Discursive processes refer to communication between members; strategic processes concern the exchange and interpretation of values and beliefs among members; contested processes involve challenging and "counterframing" (Benford & Snow, 2000, p. 626).

Bolman and Deal (1994, 1997), drawing from sociology, psychology, anthropology, and political science, identified four frames from which people regard their surroundings: structural, human resource, political, and symbolic. The structural frame stresses goals, specific roles, and formal relationships through a hierarchy of authority and rules. The human resource frame highlights the importance of peoples' needs and goals, a shared concern for others, and empowerment. Central concepts of the political frame include conflict and negotiation. The symbolic frame pays attention to an organization's symbols, meaning, beliefs, and rituals. As Tarter and Hoy (2004) claim, Bolman and Deal's frames are important in organizational functioning.

Achinstein and Barrett (2004), interested in Bolman and Deal's frames as applied to schools and teachers, adapted the model to specifically study how new teachers reframe their views of students and teaching problems. They found that teachers also use the frames to tackle negative challenges in and diagnose problems at their schools. Their managerial frame emphasizes classroom rules and procedures, illustrating how teachers develop authority. The human relations frame focuses on classroom communities and building caring relationships. The political frame sees the classroom as a mirror to the outside world, with the same conflicts, power struggles, and social justice fights. By understanding each frame, teachers can reexamine problematic situations and explore more productive options.

Methodology: Creating the Frames

Our interest in CMC began by studying the ways and the extent to which online networks were helpful to pre-service teachers (Paulus & Scherff, 2008; Scherff & Paulus, 2006; Singer & Zeni, 2004). Noting that online conversations among our pre-service teachers paralleled many of the same face-to-face issues studied by Achinstein and Barrett, and that the CMC environment (organization) seemed to parallel that of a school, we wanted to build on prior framing work by creating a frame model for our online spaces (Scherff & Singer, 2008).

At the time of data collection (2003-2004), Lisa taught English education courses at a large, public university (Southern University) in the Southeast United States. Participation in an online discussion board (Blackboard ™) was required a part of the language arts methods course which was taught during the fall semester and coincided with the students' first semester of their year-long internship. Students (n=22) were required to post at least one comment, question, and/or reply per week. The instructor was the only non-student participating in the discussion board. Over the fifteen weeks, a total of 2,209 messages were posted to the discussion board.

Nancy co-directed the English education program at a public, urban university in the Midwest United States. At Midwestern University pre-service teachers in English, speech, and theatre were required to show evidence of process and reflection regarding their teaching. They could satisfy this requirement through a paper journal, in e-mail exchanges with their university supervisor only, or through an asynchronous listserv to the entire cohort of their peers and university supervisors. For those using the listserv, there was no specific number of required messages to post nor did supervisors routinely introduce topics. Listserv members included 24 pre-service teachers and 9 university supervisors/instructors. During the internship semester, 1,343 messages were posted to the listserv; 926 of these messages were posted by students.

We approached the research from a constructivist paradigm (Guba & Lincoln, 1994; Hatch, 2002). For constructivist researchers, "individual constructions of reality compose the knowledge of interest" and spend time in "their natural settings in an effort to reconstruct the constructions participants use to make sense of their worlds" (Hatch, 2002, p. 15). Although not a physical space where we could observe for extended periods of time, CMC provided us with a front-row seat to student conversation (Scherff & Singer, 2008). Data analysis proceeded in a modified form of the constant comparative method (Bogdan & Biklen, 2003; Strauss & Corbin, 1998) and consisted of several phases. First, we reread through all postings once trying to match them with the frameworks created by Bolman and Deal (1997) and Achinstein and Barrett (2004). When our data did not fit their frames, we discussed potential frames based on findings from our prior work. For example, for both sets of pre-service teachers CMC promoted storytelling and a space to exchange teaching ideas. Once our initial frame was drafted, we selected four weeks' of online communication—weeks 1, 7, 10, and 15—that represented the beginning, middle, and end of the semesters. Then, we reread our postings and coded them according to the framework we developed. We shared these preliminary findings with each other, checking for agreement. Once 80% agreement was reached, we finalized the frame's wording and began selecting representative cases to present.

Frames for Online Organizations

Our frames highlight the ways that the pre-service teachers used CMC during their internships (Table 1). The frames not only offer a method of viewing an online organization, they show how CMC can foster reframing among pre-service teachers. In the *human resource frame*, students had virtually instant access to others who had similar issues and concerns. If participants felt afraid to ask their mentors or administrators for help, CMC provided a place for them to express their needs in a safe, supportive community. This frame helped us to understand the affective elements of online communication, but also brought up sensitive, personal issues to consider. We interpreted the *political frame* as a synthesis of ideas from both Bolman and Deal and Achinstein and Barrett. Beginning teachers have to negotiate the tensions of schools, classrooms, and relationships with colleagues. Also fundamental is the knowledge and expertise individuals can contribute. Nonetheless, without face-to-face contact, misunderstandings can occur between participants. Thus, for the sake of the community at large, the challenge for moderators is to walk the line between participant and observer (Scherff & Singer, 2008). Storytelling, joking, meaning, metaphor, and ritual are central of the *symbolic frame*, just as they are commonplace in physical organizations. For the students this frame offered opportunities to use their creative writing talents to both obtain and give assistance. At first, we found that the students were not used to the lack of structure or direction in CMC. The first weeks' postings were tentative and not very substantive. Thereafter, though, the quantity of messages rapidly increased demonstrating to us that students had become more comfortable with the openness of the online setting (Table 2).

Table 1. Scherff and Singer's Frames for Online Organizations (2008)

	Human Resource	**Political**	**Symbolic**
Central Concepts	Needs, skills, support, relationships	Networks, knowledge, expertise, misunderstandings	Stories, humor, meaning, metaphor, ritual
Metaphor for CMC	Public Journal	Community Forum	Literary Magazine
Metaphor for pre-service teachers	24-hour hotline	Roadmap (sometimes well marked and at other times not)	Social Hour
Moderator Challenge	Issues of Student Privacy and Vulnerability When to "step in" and when to "lurk" Making sure that participants do not get too off task		

Human Resource Frame
Discussions representing the human resource frame focused commonly on requests for teaching ideas/strategies, help with classroom management/discipline, and information related to university requirements. Students often used this frame to reflect upon and think through classroom problems and receive guidance from supervisors and/or other student teachers. The messages were a means for student teachers to write their way through teaching dilemmas. Using both past and present knowledge and the multiple perspectives they gained from the listserv conversations, the pre-service teachers conducted frame experiments, allowing them to test future decisions against past and current experiences (Schön, 1983). This recursive reflection may also have affected how student teachers learned to conduct themselves as members of their profession (Scherff & Singer, 2008).

Political Frame
Whereas the human resource frame provided a way to record students' support of one another, the political frame primarily allowed us to view their negotiation and resolution (reframing) of conflicts—particularly those that existed outside their own classrooms. Other times we noted a negative side to the political frame. While typographical conventions (e.g. emotions, capital letters, font) provided paralinguistic signals to help readers interpret messages, without the non-verbal and facial clues present in face-to-face conversations, misunderstandings occurred.

Symbolic Frame
For all participants, the online space functioned like an actual organization in that it had its own series of rituals, symbols, and humor that built on each other as the semester progressed. The symbolic frame became a natural component as the pre-service teachers relied on humor more than any other emotion to get them through the semester and manage the stress of student teaching, university coursework, and negotiating the schools. Posts in this frame occurred with more frequency. While both groups of students used the symbolic frame, our analysis showed that those at Southern University incorporated it more often. We believe this difference is due to the fact that at Southern University internship supervisors were not part of the discussion board; therefore, students may have felt less guarded in their online talk (Scherff & Singer, 2008).

Table 2. Number of Threads that Addressed Frames

Week #/Site	1 SU	1 MU	7 SU	7 MU	10 SU	10 MU	15 SU	15 MU
threads per week**	**13**	**20**	**26**	**16**	**52**	**5**	**45**	**11**
Human Resource	11	11	19	9	35	3	29	5
Political	4	6	6	1	6	0	2	0
Symbolic	2	1	14	2	34	0	21	1
Other	--	4	--	4	1	2	--	5

**Some threads were multiple coded; SU=Southern University, MU=Midwestern University

Testing and Validating the Frames

To test and validate the frames, we completed a preliminary analysis of online communication (wiki) between pre-service (n=70) teachers enrolled in an introduction to education course and classroom teachers (n=20) enrolled in a doctoral seminar on effective teaching at the University of Alabama. Assigned to groups of 3-5 students by content area, the pre-service teachers were asked to post reflections on their classroom observations on the wiki. Each doctoral student served as an "online buddy/coach" to 1-2 of the small groups; they were directed to respond to whatever the pre-service teachers posted to the wiki.

Our overarching questions for this phase of the study were: How or do the students frame and reframe classroom and school events? Does the form of CMC affect the framing and reframing? In particular, we are interested in (1) which frames are used most often and if there are (2) any differences in the types of talk and reflection between undergraduate and graduate students and (3) any effects that the graduate students have on the undergraduates in terms of their framing and reframing of classroom events.

In our preliminary analysis, we looked at all of the communication, a total of 44 posts, among one group's members (n=3) and their mentors (n=2) from February 1 to March 10. Twenty-six posts fit under the political frame, 22 under Human Resource, and 19 under Symbolic; in addition, half of the posts were double or triple coded.

While in our previous work, the political frame was used more to negotiate conflicts, in the present case, it was used more like a community forum to negotiate both the purpose of the wiki and how to use it. We believe this is due to two factors: (1) none of the participants knew each other well and (2) only one had experience with the wiki format. This lack of familiarity, led to "figuring things out" rather than disagreements or conflict. For example, one early post concerned what was allowed on the wiki:

> "Please correct me if I'm wrong on the following: 1) We're not allowed to use the teacher's name, 2) We're not allowed to use the school's name, 3) We're not allowed to use the students' names" (Wanda)

The human resource frame was used primarily to initiate the online relationships and set the parameters for the discussion. Adam, a mentor, made the first wiki post: "Hi everyone! Our names are Adam and Jill, and we are so excited to mentor you through your first teaching experience this semester . . ." The symbolic frame, used only slightly less than the other two frames, like in our past research seemed to start off with less frequency but then quickly became used often by the students for storytelling or responding to stories. After Adam and Jill told their teaching histories (stories), each of the pre-service teachers followed suit and told their own stories of why they were in the teacher education program. The more they wrote, the sooner—and with more frequency—humor was incorporated into their stories.

With only a very small set of preliminary data, we cannot make any definitive claims about the frames that we created or the extent to which students frame and reframe. However, based on this beginning analysis and "lurking" that we have done on the wiki, we can make two assertions. First, the wiki format is not as conducive to student discussion as an email listserv or a discussion board. Because it is another website that students have to go to (in addition to the course's Blackboard site and their university email account), it does not seem as readily accessible or present in their minds. Second, unlike emails or discussion board posts, when reading the wiki, students have to scroll through many posts to get to the most recent—this might be distracting for some, causing them to not read or post as often. The intent of the wiki—and the assigning of students to small groups—was to make students feel more open to posting their thoughts and concerns. However, it might be that this, ironically, created less collaboration. With fewer students to read and respond, the opportunities for input (reframing) were greatly reduced. Our next steps are to get feedback from the students regarding the wiki format and analyze the posts from the entire semester. Only then can any claims be made with greater certainty.

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PART III

PRACTICES ASSOCIATED WITH TECHNOLOGIES

Integrating CMC and Verbal Discussions in Students' Collaborative Learning in a F2F Classroom

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Abstract: This paper analyses the role of different communication modes in students' collaborative learning in a Primary Grade 5 blended learning environment in Singapore. Small groups of students interacted face-to-face over a CMC technology called Group Scribbles (GS) to jointly complete a learning task. We analyzed the construction and evolution of the interactions through analyzing the artifacts that are produced by a group of students - in the verbal talk, gestures, and sketches drawn and text inscribed in GS. F2F and GS interactions intertwined to support collaborative learning. The findings from this study could inform the design of integrating and reinforcing the strengths of both communication modes when introducing CSCL in a F2F classroom.

Introduction

Computer technologies play an important role in supporting students' collaborative learning. In a computer-supported collaborative learning (CSCL) environment, participants are actively and collaboratively engaged in creating knowledge, and the collaboration is taking place through a computer network. They engage in a coordinated effort to perform a task together to establish common knowledge (Littleton & Hakkinen, 1999).Various projects have examined the effectiveness of technologies that support collaboration among learners. While much CSCL research was conducted in pure computer-based settings where there is no face-to-face (F2F) interaction among learners (e.g., in a distance learning context), this paper investigates the role of networked technology in a face-to-face classroom to determine the effects of different communication modes in order to harness the synergy of both communication modes in students' collaborative learning.

There are three actors in this F2F CSCL environment: the teacher as the facilitator, the student as the task performer/problem solver, and the different communication modes as the mediator of the collaboration process. Introducing different modes of communication in the classroom provides different kinds of scaffolding and support for enabling the cognitive and social interactions between the participants involved. In this paper we examine how CMC and face-to-face interaction intertwine to support students' collaborative learning.

CMC Technology Used in Classroom - GroupScribbles

The CSCL technology used in classroom is GroupScribbles (GS) 2.0. GS user interface presents each user with a two-paned window (see Figure 1). The lower pane is the user's personal work area, or "private board", with a virtual pad of fresh "scribble sheets" on which the user can draw or type. A scribble can be shared by being dragged and dropped on the public board in the upper pane which is synchronized across all devices. It enhances the characteristics of sticky paper notes and student response system (SRS) by providing their key features while avoiding some of their physical constraints (DiGiano, Tatar, & Kireyev, 2006). It enables collaborative generation, collection and aggregation of ideas through a shared space.

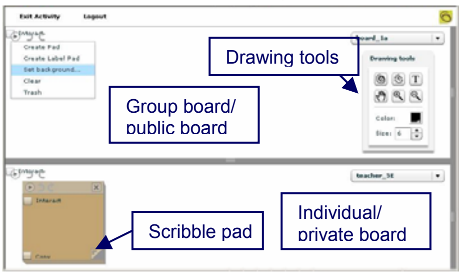


Figure 1. GS User Interface

The essential feature of the GS is the combination of the private board where students can work individually and group boards or public boards where students can post the work and position it relative to others, view others' work, and take items back to the private board for further elaboration. GS is a general-purpose collaboration tool in the sense that we do not have to need to have a pre-defined topic or task.

Context, Participants & Lesson Design

In our work with a primary school in Singapore, students from two primary 5 classes (one high ability class and one mixed ability class, each class has 40 students) have used of GS technology for a period of 1.5 years. Each week they had one or two sessions (1 hour per session) of GS-based lessons in the computer laboratory. Each student was equipped with a Tablet-PC with GS software installed. The GS was implemented in systematic learning situations where students used it to learn Science, Mathematics and Chinese language. These activities were co-designed by the researchers and the teachers and were integrated tightly with the school syllabus.

In our design, in a 1-hour GS based lesson, about half of the time was devoted to let students use GS to do collaborative learning task with the facilitation of the teacher. When doing a group task, students worked in groups of four. A typical collaborative pattern when student group is jointly doing a task is as follows: Individual group member works on the private space in the Tablet PC respectively, then posted to a group board which is synchronized to all group members. They build on each other's ideas and create the group artifact. After finishing the group task, they visit other groups' board, learn others' ideas and give comments and suggestions. Then they go back to the home group board to check the comments given by others and further refine the ideas. At the end the groups that have the best performance present their work to the whole class.

Frameworks for Interactional Analysis of Collaboration

We take the perspective of interaction analysis as the analytical tool of this study. Interaction analysis is an interdisciplinary method for the empirical investigation of human relations with each other and environment (Jordan & Henderson, 1995). In analysing interactions in CSCL environments, researchers have to take into account the construction and manipulation of representations on the shared workspace which may or may not be augmented by face-to-face interactions. Participants collaboratively build knowledge through negotiation and sharing of their perspectives on constructed/co-constructed representations, bringing upon a flow of interrelated ideas that provides the basis for the group's intersubjective meaning-making (Suthers, 2006), common ground (Clark & Brennan, 1991) and a shared world (Stahl, 2008). The works of Dillenbourg (1999) and Stahl, Koschmann & Suthers (2006) call for the need to design process-oriented methodologies to analyse interactions.

Much work in interaction analysis focuses on interactions in a text-based online environment. It is a real challenge for us to adopt an existing analytical protocol to analyze students' interactions in a media-rich collaborative environment when multiple communication modes are available. Therefore in this paper, we will analyze both face-to-face discourse as well as media representations on the CSCL environment. We will describe all the student-student and student-interface interactions in this media-rich environment by presenting the discourse, behaviour, and media representations of members of a group. Multiple point logs to analyze the interactional scripts to capture the overall picture of the collaboration process will be used. Our analysis will foreground the role of communication modes in serving different purposes when jointly doing the task.

Case Study Method & Data Collection

A descriptive case study has been carried out and one typical GS-based activity was randomly chosen. This covers a primary 5 science topic about the correct configuration of connecting a light bulb with batteries in a circuit. The students are to deduce how to connect the circuit components together in order to make the bulb light up, using on their prior knowledge of a closed circuit. This activity was carried out as a group work. The group members were seated together, facing one another. The group (the target group) we chose to examine comprised of two high ability students (Joel and Bruno), one medium ability student (Serena) and a low ability student (Agnes). Only the role of a group leader was pre-assigned. For this group, Agnes was the group leader.

The activity started by getting the students to individually sketch out their initial impressions of how to connect closed circuits with a light bulb in their GS private board. They contributed their scribble sheets to their own GS group board and then discussed as a group. This task of consolidating the ideas on the same platform will help them to infer the key similarities in constructing a working closed circuit, from the various contributions posted in their group board. The students were be also provided with some electrical components (batteries, light bulb and wires) to physically connect the circuits following the manner they had sketched earlier in GS and to test them if they would work. Later, they had opportunities to look at other GS boards to be exposed to the different ideas contributed by the other groups. They could also comment on other GS posts if they desired to do so. This would reinforce their newly learnt concept of a closed circuit with a light bulb.

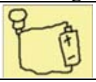
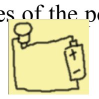
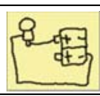
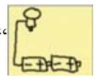
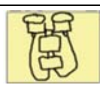
Qualitative data were obtained including both verbal and GS-mediated interactions among students. As for the analysis of the target group's interactions, researchers watched the video captured by Morae for each member of the group, and transcribed the actions and interactions within the group. In the analysis, we chose to focus on the participants' interactions regarding substantial questions/problems related to the study case. The actions included how students worked individually and collaborated on the tasks through creating or editing artifacts on GS, verbal conversation and their physical gestures.

Data Analysis & Findings

The transcripts (see Table 1) we have chosen are typical instances of the target group's interaction in the same activity. The letter in each label is used to represent the participant who had carried out the action (e.g. "B" for Bruno) in that particular segment. Each segment of interaction will be represented by a unique numerical index from the respective label. The increasing order and the sequential order of these numerical indexes represents its chronological order and its continuous flow of these segments respectively. There are omitted segments which we deem irrelevant for data analysis. The group activity transcribed here shows how the group arrived at a collection of electrical circuits' sketches on their group board as instructed by the teacher.

Table 1. Transcript of students' interaction (F2F and CMC) when working on a circuit activity together

(Researcher's interpretations, based on observations of the recorded videos, are shown within parentheses)

Label	Time	Participant	Mode	Verbal talk and gesture via F2F / Artifact & communication via GS
B1	12:57	Bruno	GS	Created "  " on private board.
B4		Bruno	F2F	(To Agnes) "Done! Agnes!" *(Tried to swivel his LCD to show Agnes)*
J5		Joel	F2F	*(Turned his head and looked at Bruno's work)*
B6		Bruno	F2F	(To Joel) "Will this do?" *(Swiveled his LCD back to show Joel)*
J7		Joel	F2F	(To Bruno) "Will, it will."
B8		Bruno	F2F	(To Agnes) "Agnes! Is this ok?" *(Swiveled his LCD back to show Agnes)*
S9		Serena	F2F	*(Looked at Bruno's screen)*
A10		Agnes	F2F	(To Bruno) "Ok." *(Stood up and looked at his LCD)*
19	12:58	All	F2F	*(The group proceeded to set up the circuit for experimentation)*
B21	13:00	Bruno	F2F	(To Joel) "No, it must be connected at the same place." *(Connected the components to construct the circuit with Joel)*
J22		Joel	F2F	(To Bruno) "See I told you! It's here!" *(Connected the wires – one wire to the metal casing, one wire to the metal tip)*
B23		Bruno	F2F	(To Joel) "Just put them at the bottom." *(Connected both wires to the metal tip)*
B24	13:01	Bruno	GS	Realized his initial plan is incorrect and undid the last few strokes of the post (from B1) to "remove" the wire on the left side and re-draw the wire connecting to the casing. He left the finalized post "  " on his private board.
T42	13:04	Teacher	F2F	(To the group) "You never draw! Draw your two batteries!"
B43	13:05	Bruno	GS	Started to draw his circuit on his private board.
T44		Teacher	F2F	(To the group) "One member draw, the other three fix the circuit."
45	13:06	All	F2F	*(The rest continued with the hands-on experimentation, then managed to construct one successful series circuit)*
			GS	Bruno finished "  " on private board. Then he posted it together with "  " onto the group board.
46		All	F2F	*(Bruno joined Joel and Serena in continuing the hands-on experimentation)*
			GS	Agnes then proceeded to sketch the series circuit out on Bruno's tablet PC, but only finished halfway at "  ".
S61	13:08	Serena	GS	Went to another group (group 2) board and saw the circuit "  " drawn on the board.
S62		Serena	F2F	(To the rest) "We all try this one. We all try this one." *(Stood up, swiveled and pointed her LCD to show Bruno)*
B63		Bruno	F2F	(To Serena) "I wanna try this one." (Agreed with Serena)
J64		Joel	F2F	(To Bruno) "Look at the board." *(Pointed the circuit on Serena's LCD which Serena was referring to)*
A65		Agnes	F2F	*(Stood up and turned her head to look at Serena's LCD)*
66	13:09	All	F2F	(The group started constructing the circuit according to what was shown in S61)
67		All	F2F	*(The rest continued with the hands-on experimentation)*
			GS	Agnes sketched on her LCD once the group had tested the circuit worked.
70	13:10	All	F2F	*(Joel initiated to build on the existing circuit and to explore with two light bulbs, then Bruno and Serena helped Joel to connect accordingly to what he wanted)*
			GS	Agnes used Bruno's tablet PC instead and started sketching.
A77	13:11	Agnes	GS	Continued sketching and posted "  " on the group board.
A78	13:12	Agnes	GS	Moved back to her seat, sketched "  ", which was according to what the rest had experimented. Then she posted onto the group board.

Task Distribution and Coordination

Task distribution includes role distribution and awareness of one's responsibility. The task was distributed – each member negotiated and chose a task. In our observation, we found that the task distribution was done via both F2F and GS. Some students explicitly talked to other group members concerning the part he/she would be working on. Another student might work on GS directly and shared his work by shifting the scribble sheet to the group/public board to indicate his/her role without an explicit verbal indication.

In T42 – 46, when all group members were doing the hands-on task, Bruno broke off from the group and took on the role of sketching the circuit, while the group continued in their hands-on experimentation. Subsequently, Agnes switched to voluntarily sketch that series circuit. In this case, task coordination was done not by verbal talk but by Agnes's behavior and the GS artifacts - Agnes noticed that Bruno was going to join the group in the hands-on activity; she had to leave the group activity for a while with the intention to sketch that series circuit. She saw the absence of the series circuit sketch and continued her task to sketch that out.

Within-Group Negotiation

Before converging towards the final solutions of all the workable circuits, the group members went through a lot of negotiations by both verbal talk and GS communication.

To understand the students' cognitive understanding of the concept, we administered a pre-test for all the students and found that three of the members (Serena, Agnes and Joel) had the prior knowledge of connecting the wires to the metal tip and metal casing of the light bulb. Bruno, though he was known to be the top student, gave a wrong answer. Serena, Agnes and Joel overlooked his circuit sketch (B1–A10) when Bruno asked them to check his answer. However, in B21–B24, when Joel and Bruno tested out their circuits they had sketched, they realized that they had conflicting views of constructing the circuit. After Joel showed Bruno his own way of connecting the bulb is correct, Bruno asked Joel to experiment using his (Bruno's) way and then he realized it failed to light the bulb. Subsequently, Bruno amended his sketch on his post to the correct one.

Many verbal negotiations were based on the GS artifacts in the group board. By sharing their work in the group board, they made their individual thinking visible to other group members. When the group members saw one another's postings, they asked one another questions, elaborated their ideas, and clarified their stands. They also refined postings according to others' comments. After the meaning-making and negotiation process, they refined the postings and finally reached shared understanding and knowledge. The end product of the group was shown in their group board GS by consolidating all group members' ideas.

Cross-Group Meaning-Making

After the group work, the students did a "gallery walk" to browse other groups' postings by clicking other group boards. This helped students to be exposed to more different ideas and different perspectives. In addition, they were required to give comments and suggestions to other groups. Then they went back to their own board to improve their own group work based on others' comments and suggestions. The interactions across different groups during "virtual gallery walk" were through GS solely as students could not verbally talk to other groups who were not seated next to them. However, the group members did discuss verbally within the group when they were browsing other group boards.

For example, when Serena browsed the other groups' boards, she was attracted by a circuit on one group board and she expressed her interest to her group members to try out that particular circuit connection she saw. The rest were interested in her suggestion and tried to test the circuit (S61–67). When the group saw that the circuit worked, Agnes drew a duplicate and posted it onto their own group board (67, A77 & A78). After the group took up this new idea, Joel continued to probe this circuit further during the hands-on experimentation (70). With the help of his group mates, he managed to develop a more complicated circuit based on the previous one by adding one more bulb and making both bulbs light up and Agnes sketched it out (A78).

Discussion and Conclusion

In the GS-based learning activity described in this study, the students built collaborative knowledge, created shared meaning, clarified the group's terminology, and created significant artifacts. We observe the construction and evolution of the knowledge in the artifacts that are produced in the group—in the sentences spoken, sketches drawn and texts inscribed. This F2F CSCL design recognizes two networks: the social network, where group members interact verbally, and the technological network that transparently supports the social network activities, by coordinating and synchronizing activity states and mediating the activities and the social interaction of the participants (Zurita & Nussbaum, 2004).

The organization of the classroom into small groups established by this model fosters the verbalization of ideas (Artzt & Armour-Thomas, 1992). With the configured seating arrangement, the students leverage on F2F discussions for immediate communication such as clarifying, referencing other work, etc. to improve on their own ideas. We observe that students often elaborated their GS ideas to each other via verbal talk. They also verbally negotiated amongst themselves before sharing their GS artifacts to the rest of the class. This study supports the findings of research on the role of verbal talk in collaborative learning - verbal language is a fundamental tool through which learners elaborate thoughts, explain results, evaluate solutions through appropriate feedback, explore and clarify inconsistencies and knowledge gaps, link the verbal information to new strategies and tangible actions, and so benefit from the cognitive restructuring that underpins cognitive change (Fawcett & Garton, 2005; Teasley, 1995).

The intertwining of online and F2F modalities play an important role in unifying and strengthening the student collaborative learning experience described in this paper. GS and F2F interactions are complementary to each other rather than supplementary to each other. Media Richness Theory (Daft & Lengel, 1986) states that the degree of richness of a communication medium is dependent on the capacity of the medium to process ambiguous communication, and suggests that richer media are more effective for equivocal tasks, and leaner media are better for unequivocal tasks. According to the theory, F2F communication is considered to be the richest, while GS is thought to be leaner since they have fewer contextual cues compared to face-to-face (Daft & Lengel, 1986). Effective collaborative learning often involves both equivocal and unequivocal tasks. Thus it would be ideal if we can combine both types of interactions to support deep and meaningful collaborative learning in real classroom settings. While F2F interactions enhance small group meaning-negotiation, GS enhances classroom communication across different groups. GS provides displays that reveal what students are doing, thinking and understanding. Student's contributions are stored for future reference, providing the affordances for the whole class to construct knowledge together. Teachers can use the information provided through GS to augment the natural communication flow of the whole classroom. Both media enhance the development and quality of the content of the discussion and the collaborative process by encouraging the exchange of ideas and by fostering participants' interdependence.

The findings from this study can inform the design of a blended learning environment. The issue of how to balance the F2F and CMC components is still a challenge for blending learning environment design. A variety of preconditions, such as the socio-cultural context, the curriculum, the course, students, teachers, and resources, will have an effect on the balance of the communication medium. Further analysis is needed to probe the relationship between GS and F2F in other scenarios (e.g., different subject or topic areas, different types of task, different group formations).

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Making classrooms socio-technical environments for supporting collaborative learning: the role of personal devices and boundary objects

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Abstract: The emergence of low-price computers has made possible numerous new ways of classroom learning. The personal devices that are applied in a manner without interoperation with appropriate peripherals may interfere with face-to-face collaboration since the personal devices were design for personal usages. To improve the collaboration that takes place in small face-to-face groups in repeated episodes, we seek to strengthen relationships by encouraging non-verbal contact, which is known to be a key component to increasing intimacy in personal relationships. Through gathering the small group learning interactions in a collaborative learning scenario, this study proposed that classroom environments require, in addition to personal devices, special design of boundary objects to sustain and support social learning activities. An experimental classroom was developed with LCD displays and shared-display groupware. Analysis of student learning activity found that students working with only personal devices tended to learn together in a disjoint interaction pattern. Contrarily, in the environment with shared-displays as boundary objects students demonstrated a joint and coherent interaction pattern since they took more notice of the shared group work.

The power and limitation of one-to-one collaborative learning

Classrooms have been considered importance places where learning takes places in formal education. The emergence of low-price computers and wireless network has made possible numerous new ways of classroom learning. The notion one-to-one (1:1) was addressed to refer to the new learning scenario where students bring personal devices fitted with wireless communication capabilities into classrooms and apply these devices for various learning activities. Examples of these personal devices include Personal Digital Assistants (PDAs), OLPC (One Laptop per Child), Classmate PCs and Eee PCs. Some of these personal devices have been confirmed for their effect in improving classroom learning in the following ways: they connect the classroom to the outside world (Liu *et al.*, 2008); contextualize learning experience (Hsi, 2003), and act as extended minds (Clark & Chalmers, 1998) in the classroom. However, the personal devices that are applied in a manner without interoperation with existing peripherals such as displays devices and whiteboards in classrooms may interfere with face-to-face collaboration since the personal devices were design for personal usages (Liu and Kou, 2007).

The effect of personal devices on facilitating collaboration was specially addressed because these devices enable students to contribute personal experiences to collective thinking in classroom (Zurita & Nussbaum, 2004; Chen *et al.*, 2005; Roschelle, 2003). In addition, the availability of personal devices has changed the way how students managed their learning work and learning portfolios. At the time when personal devices were not widely affordable, students stored their coursework, reading materials, personal collections of websites and life notes in their tabletop computers. These portfolios were transferred and mirrored from tabletops to their laptops. The personal devices become the main repositories of personal work and learning portfolios. The personal devices may enrich the classroom learning since various artifacts collected across different contexts, locations and time were brought to classrooms that fulfill a seamless learning scenario (Chan et al., 2006).

However, the socio-technical environment through which personal resource, perspective, and work can be smoothly contributed, exchanged and integrated is not commonly supported in classrooms, despite the availability of personal devices. The classroom model that we commonly adopt was designed based on the requirement of instruction-oriented activity. Facilities such as backboard, podiums and the way seats were arranged mainly support passive learning scenarios in which students play the role of information receiver. It's rare in our classrooms that students contribute personal materials to the classroom that help to obtain a global integrated information set on which the class can reflect on. Information and knowledge sharing take places only in personal devices rather than in a place where all group members can jointly reflect upon. In addition, a lack of shared workspace may lead to loss of eye-contact and unawareness of visual focus (Scott et al., 2003). It was confirmed that naïve applications of personal devices do not guarantee improvement of interaction in classrooms and may lead to fragmented and tête-à-tête interaction patterns (Liu & Kou, 2007). Therefore, a socio-technical design that invites student contribution is required to support and sustain collaborative learning activities when students have their own computers in classrooms.

The concepts of socio-technical environments have been extensively applied in different areas to promote the collaboration and facilitate the mutual understanding of members. Socio-technical environments (Trist, 1981) refer to as the living entities that are capable of integrating computing infrastructures and participation processes supporting collaboration (Fischer, 2007). The socio-technical environments address the role of technology in facilitating knowledge sharing across boundaries between stakeholders and the role to improve congruence between participants to trigger social activities (Mumford, 2000). However, it is still unclear how the personal devices can cooperate with classroom entities to support the social learning activities and avoid the negative effect of these personal devices. It is therefore necessary to redesign classroom environments that may help to transform the classroom learning practice into collaborative learning experiences.

Different devices may afford different functionalities that can support a certain learning context. It is required to integrate different functions of devices to support learning activities in the physical environment (Bollen, Giemza and Hoppe, 2008).

Therefore, this study argues that instead of concerning only personal devices, the scope of one-to-one collaborative learning should extend to socio-technical environments that involve collaboration entities in the classroom. This study proposes an important classroom socio-technical entity, boundary object (Star, 1989), which should be included in classroom settings to facilitate collaborative learning. An experimental classroom was developed to support collaboration by using large LCD displays and shared display groupware as integral boundary objects to externalize the ideas of different participant. A group problem-solving activity was conducted in the classroom to examine the role of personal devices and boundary objects. By gathering and analyzing student collaborative activity, this study was conducted to explore what and how classroom technologies may cooperate with personal devices to augment collaborative learning experience in classrooms.

The socio-technical classroom

Trist (1981) first proposed the term socio-technical systems that address the close interplay and cooperation relationship between the social and technological systems. The socio-technical analysis of environments thus highlights the interweaving of social and technical factors in the way people work (Pan et al.,1998). From the social-constructivist view of learning, the role of classroom is not only to facilitate the acquisition of knowledge. It also has to be able to engage students in joint coherent knowledge construction activities with peers and teachers. Therefore, it is necessary to analyze how the technology affects the social activity in the classroom and identify what technical refinement should be made to best use personal devices.

In the context of collaborative learning, knowledge advancement involves a social process in which participating actors of different backgrounds cooperatively negotiate to reach convergent understanding from diversity of ideas (Roschelle & Teasley, 1995). One concept that can explain how workers/learners manage both diversity and cooperation is boundary objects. Boundary objects are shared repositories, externalized representation, work places, or communication methods through which all actors can interact by providing a shared reference that is meaningful within all actors (Star, 1989). For example, In Star's example, museum and libraries were boundary objects where all actors from different worlds could share, use and borrow artifacts for their own purposes. However, boundary objects do not always emerge naturally between all actors. "*The creation and management of boundary objects is a key process in developing and maintaining coherence across interesting social worlds* (Star, 1989, pp.393)".

Classrooms we customarily used today do not have special mechanism to help create and maintain boundary objects that appears in a digital form. It's not easy for all students to interact with each other by providing and accessing a shared reference to the digital artifacts in the personal devices. In addition, the fact that students work and discuss using only their own computers reduces non-verbal contact between students (Zurita and Nussbaum, 2004, Scott et al., 2003) which may create distance between members (Argyle & Dean, 1965). This study thus considers boundary objects that locate at the border between individual students and devices integral to promote and engage learners in collaborative activities. Through interacting with appropriate boundary objects, it is hoped that participants resemble a coherent organism to work with all aspects of artifacts.

To support collaborative scenarios with personal devices, the classroom model of this study includes shared display groupware as a critical boundary object of socio-technical environments (Fig. 1). Shared display groupware (DiMicco et al. 2004) were expected to facilitate collaboration by promoting shared understanding of distributed group artifacts and increasing awareness of partner actions since participants can get close to one another's center of visual focus with the shared display. The groupware displays either personal device screens or shared documents in their personal devices on the shared displays. Students can then clearly view the shared documents and personal device screens of others via the large shared displays that enable all participants to work together on the shared display. Additionally, instead of adopting flat-panel monitors, which are commonly adopted with computers, the workspace adopts 16:9 and 32-inch diagonal widescreen LCD displays. The LCD displays are more suitable for group learning than computer monitors, since they have wider view angles and screens. Since group partners work in the shared workspace rather than in personal devices, students are more likely to conduct intimate behaviors such as eye contact and shared visual focus that sustain intimate social interaction.

Figure 1. A socio-technical classroom model with shared displays

The collaborative learning scenario and evaluation

The experimental classroom was first setup in 2005 and after then there were several courses were conducted in this classroom. This study collected and analyzed student learning activities in a collaborative learning scenario to investigate how the boundary objects between personal devices affect collaborative learning.

The participants were fifteen graduate students enrolled in the course "Statistics and Data Mining Techniques," at National Central University (Taiwan). Students solved the statistics problems assigned by the teacher collaboratively in the experimental classroom. The students were divided into three groups. The teacher presented problems, which the students had to collaborate to solve. To enforce personal accountability, students were asked to solve the given problems by themselves before discussing them with their peers. Group members then conferred with each other to organize a group solution. The interaction between group members and the process of discussion was observed in order to gain an understanding of how they interacted with the aid of personal devices and boundary objects.

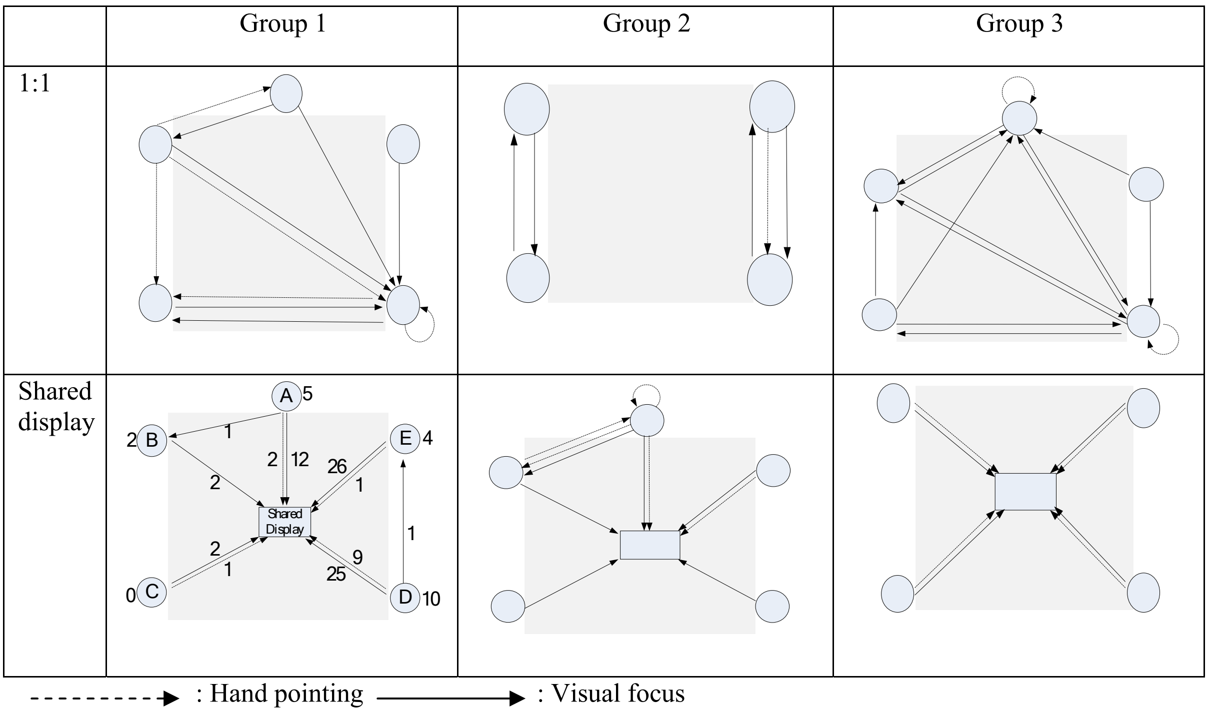

Figure 2. Non-verbal interaction patterns of groups in two different settings

This study assessed peer interaction as influenced by the use shared-displays groupware as the boundary object. Thus, the group problem-solving activity was carried out in two different environmental settings, namely 1:1 and Shared-Display. In the 1:1 setting, students used only the Tablet PC for both individual learning tasks and collaborative learning activities in the classroom. In the Shared-Display setting, students could utilize shared display groupware with personal devices in the group problem-solving activity.

To integrate non-verbal interaction with conversational analysis, this study analyzed the conversational and non-verbal events that occurred during the collaborative problem solving activities. Both conversational and non-verbal interactions were collected for further analysis. Because the interaction took place in a conversational format, the chronological order of the conversational utterances was analyzed to reveal the uptake relationship in conversation based on chat log analysis framework (Stahl, 2005). Two independent coders identified discussion threads, each of which represent a continuous set of connected utterances related to a topic since conversation topics kept changing. A new discussion thread was started when a student presented a new group development statement, position, or argument that was not related to previous discussion threads. In addition, this study also analyzed non-verbal interactions to reveal more details of interaction patterns since some social cues were not available in conversational records. These non-verbal cues included (1) watching personal devices, (2) pointing at personal devices, (3) watching the shared display, and (4) pointing by hand at the shared display.

Fig. 2 displays the non-verbal interaction pattern demonstrated by the three groups in 1:1 settings and in the environment with shared display. Each round node in the patterns represents a student. The number next to student node displays the number of discussion threads initiated by the student. In addition, an arrow pointing to another student indicates a student was looking at another student's personal screen. This study analyzed students' visual focus during each utterance of student conversation. The number attached to an arrow represents the frequency, i.e. the number of utterances, during which a student took visual notice on a certain device. Similarly, dotted arrows represent students' hand pointing behaviors.

The non-verbal interaction patterns revealed that interaction was largely affected by the positional configuration. In 1:1 setting, most non-verbal interactions occurred between students who sat next to each other. One exception is the interactions between student D and others in group 3 since the student took the leader role and initiated many discussion threads. The boundary objects, i.e. the shared displays, also profoundly affect student interaction patterns. Students in the shared display setting demonstrated rich hand pointing behaviors. On the contrary, students in 1:1 setting rarely demonstrated such behaviors. In addition, students demonstrated a joint and coherent interaction pattern since they took more notice of the shared group work. Students' visual focus concentrated on the shared display where the group works was conducted. The analysis of interaction threads also found that students exhibited different degrees of participation in the two settings. In the 1:1 setting, an average of 2.20 students joined in each discussion thread. In other words, most interactions occurred between only two students. In the Shared-Display setting on the other hand, each discussion thread attracted the participation of an average of 2.97 students, significantly exceeding the thread participation rate of the 1:1 setting ($t=-5.777$, $p<.01$).

Conclusions and implications

This study found students working with only personal devices tended to learn together in a disjoint interaction pattern in which only limited intimate social interactions were observed. On the contrary, students learning with each other through both boundary objects and personal devices demonstrated a joint and coherent interaction pattern since they frequently took notice of the group work and showed rich hand pointing behaviors. The difference in interaction patterns demonstrated by students in the two different settings revealed that boundary objects were critical because they help to attract students to interact with one another and engage in group activity, rather than to work alone with personal devices.

The development of low-price computers has made many new classroom learning scenarios possible. Although groupware applications could be built in the personal devices to improve classroom learning experience by enforcing social learning activities, the investigation into socio-technical classroom design that attracts and facilitates students to learning with peers remain limited. This study therefore applied a socio-technical approach to examine the interaction requirement of a classroom design that can cooperate with personal devices to support effective and lively collaborative learning. Through gathering the small group learning interactions in a collaborative learning scenario, this study proposed that, in addition to personal devices, classroom environments require special design of boundary objects to sustain and support social learning activities. It was found that the LCD displays, together with appropriate groupware in the classroom were useful to make classrooms a socio-technical environment to support group learning form both cognitive and affective perspectives. Designers of classroom technology may need to know the power and limitation of personal devices. Different styles of boundary objects, such as the shared display groupware, may be designed to promote the face-to-face interaction in collaborative learning with personal devices.

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What have you done! The role of 'interference' in tangible environments for supporting collaborative learning

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Abstract: This paper presents a study that investigated collaborative activity in a tangible tabletop environment to support learning about the physics of light. In co-located groups of three, children performed exploratory activities, using tangible artefacts, to find out about light. Analysis suggests that the environment can support various collaborative activities, but of central interest, demonstrated the role of peer interference in learning activities. Verbal negotiation and synchronization of actions emerged as conflict-resolution strategies and an implicit agreement by the children for sharing the physical and virtual resources of the system was noticed. The physicality and 'present at hand' nature of the input devices contributed to balanced levels of participation, particularly through action. Overall, the interference-prone tabletop environment contributed to creating a highly collaborative environment in which individual exploration was discouraged, leading the group through a productive process of collective exploration and knowledge construction.

Introduction

Tangible and tabletop interfaces offer new opportunities for collaboration in digitally augmented spaces, particularly due to the facility for multiple simultaneous input, and the sharing of physical resources. The value of tangible and tabletop environments has been demonstrated in terms of engagement and enjoyment (Xie and Antle, 2007), intuitive interaction and appeal for collaboration (Morris et al., 2006; Piper et al., 2006). However, much research to date on shared interfaces has focused on CSCW (Computer Supported Co-operative Work). Shared interfaces for co-located collaborative learning pose different challenges, and little research has yet investigated how collaborative interactions around tangible tabletop environments might support learning.

Shared interfaces are considered appealing for collaboration and learning for a number of reasons. Shared interfaces can support co-located interaction for multiple users to simultaneously interact with digital information (Sharp et al., 2007), and are shown to provide more equal access and participation (Rogers et al., 2008). Tangible-based interfaces also provide tools for mediating new kinds of external representations, potentially supporting new forms of collaborative interaction and learning. Interaction centres around physical action and manipulation of multiple objects offering opportunities to build on everyday interaction and experience with the world, and opportunities for expression and communication through action. This sits in contrast to mouse-based interaction where mappings between action on object or virtual representation are indirect. Furthermore the use of physical artefacts can provide a more fluid way of sharing control, and encourage participation of reticent users (Rogers et al., 2008).

Tangible technologies, in the form of physical artefacts coupled with digital information, allow access to more or different information than is normally available in the immediate physical environment. The close mapping of physical properties of objects to the learning domain, and direct mapping of manipulation and action to digital output can illustrate domain concepts more explicitly. However, such environments are also inherently dynamic, comprising multiple representations and transient information, and where both physical and digital representations can change in form, space or time. This results in an environment with multiple representations and transient information (e.g. Stenning, 1998; Price, 2002; Ainsworth, et al., 2002), and the effect on reasoning and collaborative interaction for learning needs further investigation.

As part of an ongoing research programme, this paper presents a study that explored collaborative activity in a purpose built tangible tabletop environment to support co-located learning about the physics of light. This investigates how shared interfaces affect the way that collaborative activity is structured, and examines the kinds of collaborative interactions that are productive for learning, and in particular, the role of parallel actions with physical interaction devices in mediating collaborative activity and communication that supports learning. Analysis indicated the role of interference through action in structuring and mediating collaborative interaction and communication, both verbal and physical. The findings are discussed in relation to levels of participation, interference from action in a rapidly changing dynamic environment, and its effect on curiosity, exploratory and inquiry activity, negotiation and synchronization of actions, sharing and control of resources and the subsequent implications for collaborative learning.

Related work

Shared interfaces for co-present collaboration, are designed for multiple users to simultaneously interact with digital information (Sharp et al., 2007), aiming to provide more equal access and participation, with a more fluid way of sharing control (Rogers et al., 2008). Shared interfaces can be implemented through Single Display Groupware (SDG) (Stewart et al., 1999), tabletops, and tangible interfaces. In SDG environments, co-located users interact with a system via multiple input devices getting feedback from a single output display (usually screen or wall). Tabletops can be viewed as face-to-face SDG's as opposed to the shoulder-to-shoulder interaction promoted by vertical displays (Piper et al., 2006). Much research on tabletops focuses on multi-touch interfaces (e.g. SenseTable (Patten et al., 2001), SmartSkin (Rekimoto, 2002) and DiamondTouch (Deitz and Leigh, 2001)) as opposed to interaction through physical devices (Reactable (Jordà, 2003)). Recently, however, the implementation of tangible interfaces through tabletop surfaces has become more common. The kind of interaction they provide comes closer to traditional tabletop activities and allows alternating between individual and collaborative use (Scott & Carpendale, 2006). This paper explores co-located collaboration in a learning context using a tabletop display surface with tangible input devices.

One of the advantages of shared interfaces for collaboration is the potential of multiple input devices. One strand of related work has explored the use of multiple mice with traditional computer interfaces. Studies with children indicate higher levels of activity (Inkpen et al., 1999); less time off task (Inkpen et al., 1999; Stanton et al., 2002a); less monopolization of the task (Stewart, 1999) greater equity of activity (Stanton et al., 2002a); higher levels of motivation (Stanton et al., 2002a); and more effectiveness of task completion (through parallel or co-operative work) (Stanton et al., 2002a). However, shared control was also shown to result in less collaboration due to parallel working without having to share the input device (Stewart et al., 1999); and less verbal reciprocity (Stanton et al., 2002a) with little elaboration of ideas as children were primarily engaged in their own actions (Stanton & Neale, 2003). Enabling more equal access to the physical input devices by decreasing the competition for access (Stewart et al., 1999) does not directly imply an increase in collaboration.

Another strand of work focuses on physical artefacts (multiple input devices) as resources to support collaboration and shared understanding (e.g. Stanton et al, 2002b; Rogers et al., 2008)). With *Kidpad* (Stanton et al., 2002b) the visibility of actions characteristic of tangible environments were found to make users aware of the collective action during synchronous interaction, though asynchronous interaction was reported to allow reflection and reaction time. The action with inputs was identified as important in aiding collaborative behaviour. For instance, children often collaborated through action without verbal communication and observed others' actions interrupting or reacting accordingly (Stanton et al., 2002b). Furthermore, children would assume tutoring roles to help each other out (Stanton et al., 2002b). Rogers et al.'s (2008) analysis of participation and collaboration using a laptop, a multi-touch tabletop and a tabletop with physical artefacts as input devices, showed that the physical objects enabled groups to systematically consider and discuss different possibilities. Also, participants who spoke the least demonstrated high levels of physical activity, suggesting that physical devices allow reticent users to contribute to the activity in non-verbal ways. External representations and artefacts are also thought to play a key role in shaping thinking (e.g. Wertsch, 1998; Scaife & Rogers, 1996) through their ability to both constrain and enable thinking and acting. Crook (1995) claims the value of referential anchors in the form of external representations in supporting construction of shared understanding. This paper explores the use of multiple physical artefacts as input devices and external representations in supporting and structuring collaborative activity.

The potential for increased conflicts and interference in shareable interfaces through incompatible actions and behaviours has also been highlighted (Stewart et al., 1999; Morris et al., 2006; Hornecker et al., 2008). Comparing different input devices on shared interfaces, Hornecker et al. (2008) suggest that multi-touch (as opposed to mouse based) interaction generates more "clashes", but leads to greater awareness of others actions, and more fluid interaction. Furthermore, conflicts may emerge from parallel work when users try to perform incompatible actions (Stewart et al., 1999). Morris et al. (2006) report conflict behaviours in document sharing, and suggest the need for coordination policies, to increase group awareness and encourage a sense of involvement. In learning contexts forms of conflict have been identified as being important catalysts for conceptual change, for example, through forms of cognitive conflict (Piaget, 1967) or perturbation (Laurillard, 1997). Collaborative learning contexts in general extend opportunities for such conflicts to arise through peer-peer discussion and negotiation or adult-child and even computer-child interaction. The resolution of conflicts and co-construction of ideas and repairs following misunderstandings indicate highly productive collaborative interaction (Roschelle & Teasley, 1995; Stanton & Neale, 2003). However, little is known about the occurrence and effect of action clashes in shared interfaces for learning, particularly within an environment designed to support exploratory discovery learning, and whether they inhibit or support co-construction of knowledge. This paper discusses the effect of 'interference' on various aspects of collaborative interaction and learning.

The benefits of collaboration, from a learning perspective, depend on the styles of the collaborative behaviour (Stanton & Neale, 2003), and the nature of the activity and learning domain (Stewart et al., 1999; Stanton & Neale, 2003). Wegerif & Scrimshaw (1997) address the "educationally important talk"; Littleton

(1999) suggests the computer not only supports collaboration, but transforms the way in which collaborative activity is structured. Within creative, problem-solving, or exploratory environments, collaboration may support co-constructing a story or resolving differences of opinions, where sharing ideas and perspectives is more important than efficiently producing a final answer. This paper involves an exploratory learning environment where the process of knowledge building is central rather than production of a particular answer.

A large body of the research focuses on how computers and technologies can support collaborative learning through communication, primarily through verbal interaction and social negotiation. A key aspect of this involves challenging others about their views, as well as reaching an understanding of their world through collective agreement (Piaget, 1967; Vygotsky, 1978). Furthermore, externalisation through verbal expression in the form of self-explanation, is shown to make explicit to oneself and (in the context of collaborative activity) to others, any discrepancies in understanding, providing opportunities to revise thinking and understanding (Chi, 1997). A part of such verbal interaction creates "conflicts" which are shown to enable higher performance than if working alone (Crook, 1998). However, cognitive or social conflict alone is not necessarily predictive of conceptual development, Scardamalia & Bereiter (1993) emphasising the importance of the explanation accompanying the conflict as a mediating factor in knowledge building. Primarily communication has taken the form of verbal interaction, expression, and argumentation, with less understanding of the role of action in the collaborative dialogue. This paper discusses the how communication may be supported in collaborative environments through action, and in combination with verbal interaction.

The tabletop environment

An interactive tangible tabletop environment was built based on reacTIVision technology (Kaltenbrunner & Bencina, 2007). The software application developed (in Processing language) to run with the table aims to support students learning about the behaviour of light, exploring concepts of colour and light reflection, transmission and absorption. In the context of this application, interaction with the system is enabled exclusively through a set of concrete objects: several different coloured plastic blocks and a torch tagged with fiducial icons (Figure 1). The objects are only recognized when fiducials are facing down (in contact with the table surface), enabling the camera placed underneath the table to see them and identify each particular object and its location.

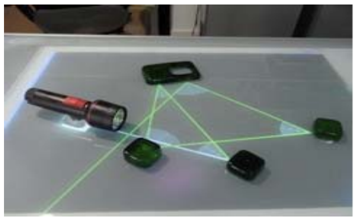

Figure 1. Objects tagged with fiducials (left) and their position on the table (right).

Multiple objects can be simultaneously recognized, enabling several users to interact at the same time. Visual effects projected on the tabletop show light reflection (Figure 1, right), absorption, transmission and refraction, triggered by the interaction amongst the torch and the blocks on the table surface. As the torch is the only source of light in the application, all effects are dependent on its presence on the table. Placing the torch on the surface immediately produces a white light beam, and all other effects result from the interaction of this beam with the concrete blocks. Similarly, removing the torch from the surface causes all effects to disappear.

Different objects (Figure 1, left) were designed to illustrate each phenomenon: square coloured blocks reflected light; rectangular coloured blocks with holes (as a way of 'seeing inside' the object) illustrated reflection and absorption; and transparent blocks showed transmission and refraction. "Digital light" travels in the environment respecting laws of reflection and refraction, thus even subtle rotations of an object changes the angle (and direction) of the reflected beam and affects the whole arrangement on the table.

Studies

A study was undertaken to evaluate the tangible environment in terms of engagement, collaboration, and the effect of locations and metaphorical mappings (Price, 2008). In this paper, we focus on the findings relating to collaboration.

The study involved 21 children aged 11-12 years (11 female and 10 male), from Year 7 classes of two schools in the outskirts of London (UK). Children worked with the tangible system in groups of three, consisting of a mixture of girls and boys, making 7 groups of children. Each session lasted 35-45 minutes. Some children were aware of basic 'light' concepts such as light traveling in straight lines, shadows, and opaque and transparent objects. They were told that they were not being assessed or evaluated and there were no right or wrong answers, but they were expected to use the system to find out more about the behaviour of light and express their opinions and ideas. The system was therefore designed to support exploratory interaction to support knowledge construction of the domain, rather than to complete a fixed task with a final answer.

Children were initially given five minutes of free play to familiarize themselves with the system. Few instructions were needed, as the environment was very intuitive and pupils were able to interact easily. The facilitator prompted the group only where necessary with general questions such as *"what's happening here?"* and *"why do you think this is happening?"*, to guide students through the exploration of the concepts towards making inferences and drawing conclusions. Eventually, the facilitator called children's attention to particular objects or phenomenon, or to ask children how they could find specific information or produce a particular effect. At the end of the sessions, post activities consisted of using transparent objects that behaved as coloured ones. The aim of the activity was to verify whether children had grasped basic concepts regarding the relationship between colour and the physics of light behaviour (i.e. a green object reflects green light from the white beam).

All sessions were video-recorded. After engaging with the tangible system children were informally interviewed in their groups to obtain information on their understanding of key concepts of behaviour of light, feedback on the usability of the system as a whole, and their general experience.

Key findings

Findings based on collective qualitative analysis of observation, video data and interview data, focused on collaborative interaction in the tangible environment. All of the children expressed their enjoyment from interacting with the environment, and indicated that it would help them remember what they had been doing "*because it was fun"*. All the children found interaction with the objects and table unproblematic. Evidence from their interaction, and their explanations with demonstration to their teachers following the activity suggest that children were grasping the concepts being explored. The findings presented here centre around the role of combined artefacts, action and representation in supporting collaborative activity, both physical and verbal.

The Role of Interference

When using the tabletop environment, children interacted both physically (taking complementary or opposing actions) and verbally (contributing to one another's ideas or giving orders), and both in terms of how the environment works and in terms of the concepts of light. By building on each other's ideas and actions, they could reach a collective understanding. The facility of tangible environments to support action on external representations, means that interaction is centred around moving and manipulating objects, and action becomes the central mediating factor in the collaborative interaction. Thus, the design features of the environment supported a high level of physical interaction. Shared interfaces also support multiple users to simultaneously physically engage in the environment. This means that sequential collaborative activity is not necessary, and concepts of turn-taking are not embedded in the functioning of the system. The analysis showed that such design features promoted episodes of interference, both physical and verbal. Although this sometimes caused interruption in activity, e.g. where children were prevented from building an arrangement to explore a concept, our analysis revealed the positive role of interference in providing opportunities to challenge children's thinking and understanding about the concept and promoting reflection through unexpected events. Despite having to deal with rapid and uncontrolled changes, one may benefit more from having other people's interference (bringing more challenge and variety of situations) than from performing actions on one's own, or through a rigid sequential turn-taking process. In this section, different forms of interference and the contexts in which they were observed are described and discussed, considering their role in a collaborative learning process.

Effects of Local Actions x Global Interference

The fact that the environment presented in this paper accurately modeled the theoretical phenomena we were exploring meant that it was extremely dynamic: moving any object involved in a particular arrangement affected all digital effects displayed. Very small (and even unnoticed and unintentional) changes may "destroy" the current configuration. For example, a blue object placed on a red beam will "stop" the beam, whereas a red one will reflect the light, therefore changing the direction of the beam. Thus, when one child decided to try something out while another child was working on the current arrangement, or using it for explanations, this interfered with another's activity. For example, while one child was trying to find out what happened with white light on a transparent object and then onto a further object, another child placed a red object between the torch and the transparent object, thus blocking the pathway of the light beam to the transparent object. On other occasions, while one child was responding to facilitator and using the table to verify answers, the others used the blocks to do something different, interrupting the attempt to focus on one particular idea. Although the children may think they are only dealing with that particular object or area of the surface, and may not notice their own interference in another's actions, the effect will be widespread if the local action involves the beam of light. While it may be difficult to control the changes when the group is dealing with many objects at the same time, our findings suggest that this "unintentional interference" promoted productive effects on the interaction and collaboration, and in particular stimulated curiosity (promoting reflection) and effective coordination of actions towards common goal and understanding. For example, when trying to understand reflection from multiple objects, one group collectively built an arrangement on the table (Figure 2, left), then suddenly the digital reflected rays vanished (Figure 2, right), causing general surprise (*"oh, what!"; "what happened?"; "you moved the torch!"*). One of the children then moved the torch, producing different effects and promoting discussion about reflection *("reflect back to the white light"; "it's not reflecting on the white light")*.

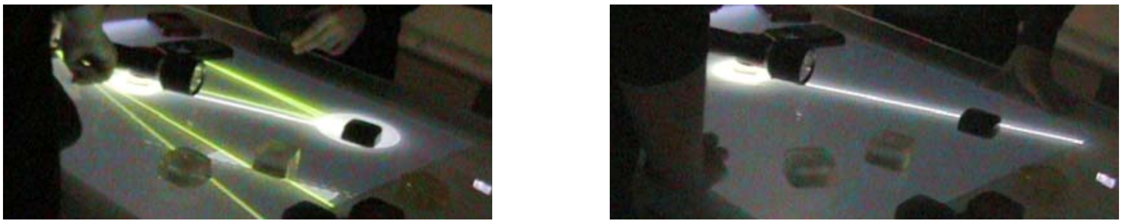

Figure 2. Unintentional interference leading to complete changes in configuration

The parallel actions, favoured by the multi-user feature of the interface and the collection of objects available, provoked rapid and continuous changes to the digital display in relation to the physical objects. Often this led children to request peers to *"stop – leave it, leave it"* or to slow down (*"wait, wait – what was that?"*) when they wanted to see what was happening. Drawing on research on animation (e.g. Price, 2002), which suggests that dynamic representations may be problematic for learning, particularly due to the speed in which things change during interaction, would suggest that there may not be enough time for reflection on each configuration. In some cases, children would take turns and act sequentially, allowing more time to think. However, with the tangible tabletop interface the immediate effect of actions performed with the input devices allowed the children to identify that others' actions had caused the changes. Evidence of their attention to each other's actions or speech were apparent in exclamations like *"what have you done!"*; *"you've moved the torch!"*, and rhetoric questions such as *"what's that?"*; *"what have you got on there?"*; *"what about this one?"*. In instances like this, when the relationship between action and effect was unclear, interference provoked curiosity, an important stimulus for conceptual development (Lehtinen et al., 1999; Price et al., 2003), and drew children's attention to the phenomena caused by others. This led to group explorations through action and verbal interaction of the particular 'light behaviour', engaging them in a knowledge production process. As an example, when asked by the facilitator what happens when objects of the same colour are used simultaneously, a group started experimenting with green blocks. At first, the girl had not realised green light would reflect from green objects, until she saw the boy producing such an arrangement (*"oh, yes, you can!"*). Trying to formulate an explanation, the boy suggested *"because it's the same colour, is it?"*, to which the girl added: *"so it makes it able to bounce off"*. The girl then decided to build on the current arrangement adding other green blocks, but the boy interrupted her plans by moving the first block she had placed. After asking him to *"put it back"* the girl tried placing another block on the green beam, but accidently captured the white beam instead, completely changing the configuration, to her own surprise (*"what did I do?"*). The boy took out the block explaining that she had put it in front of the white light. The third child in the group then moved the torch, causing instant reactions of *"no, no, leave it where it was!"; "put it back there"*. As they still struggled to rebuild an arrangement with multiple reflections, the children made comments like *"it's not reflecting";"but it was reflecting!"* Thus, combined action with the rapid dynamic changes of the environment mediated productive episodes of collaborative interaction focused around the phenomena being learned.

At other times the relationship between others' actions and the resultant digital changes were apparent to the children, and enabled them to request, for instance, a block to be taken away so that the on-going exploration of a current configuration could be continued, or some action to be repeated to be analysed (*"do that again"*). Collective activities were sometimes hard to perform: for example, when a group tried to reflect light off several green objects, with each child controlling one object, they initially kept moving them, thus changing the direction of light and making it difficult to get it to bounce off all of them. In instances like this, awareness of action promoted the development of negotiation and synchronization between the children. Overall, constant interference led to a unique focus of attention within the system, serving to draw attention to relevant instances of the phenomena, generate inquiry around those instances, and support effective collaborative activity.

Encouraged by the continuous interference inherent in the system, children instigated engagement in a collective process of knowledge production. Once they became more aware of the global effect of their actions, they understood that they needed to coordinate in order to achieve their goals. Both verbal and physical negotiation emerged during this synchronization. In groups where one child stood out as a leader, verbal orders would be common, such as *"put all the green ones"*, *"shine it there"*, *"move it round"*, *"put it back"*, *"reflect light into that"*, *"put this in front of there"*. Through those orders, the child tried to decide the flow of the activity and build arrangements as they wished, still having the participation of the rest of the group, but keeping it somehow under their control. The synchronization was also done in a more democratic way, when children invited peers to collaborate: *"can we try that one?"*, *"let's try this one"*. Children also reported their own actions, making peers aware of what was going to happen: *"I'll turn it on"*, *"I'll put that orange one in front of the torch"*; or would simply call attention to their actions: *"look! Look!"*. After a discussion with the facilitator about white light being made of different colours, one group decided to *"put them* [the objects] *all together, it probably makes white"*. While the others assembled the objects, one child held the torch, and then pointed it towards the blocks. In this way the environment supported constructive child-negotiated collaborative activity.

Sometimes a child would directly and intentionally interfere in their peers' actions or arrangements, though in a constructive manner, like: giving demonstrations (for example, one girl moved a block on the table and told her friend: *"if I put this here… you lost your colour"*, rebuilding the previous configuration afterwards: *"now you've got your colour again"*); giving helpful instructions (e.g. showing how to make the system work: *"you have to put it down"* or when a peer was trying to achieve something *"if you put it down that way and take that out…"*); collectively exploring the system (building on each other's actions to test their own hypotheses while thinking aloud *"what happens if…", "what if I do this…"*). These instances of interference illustrate how the environment encouraged externalization, both through verbal explanation and through action in the form of demonstration. In one instance, a boy was making assumptions on an arrangement in which a light beam was going through a transparent block and subsequently reflected by a yellow block (Figure 3, left). A girl then interfered by changing the order of blocks and showing that the light would no longer reach the transparent block; the boy agreed, but added that they would still get reflection off the yellow block (Figure 3, right).

Figure 3 Direct interference leading to reflection on concepts

Impact of Controlling and Sharing Resources

Besides the interference caused by the global effects of users' actions, the design features of this tabletop environment also encouraged particular kinds of group interaction through the input devices: namely, the torch; the virtual resources or digital effects; and the physical blocks. These were noted to affect equality of collaboration, control of the activity and sharing of resources.

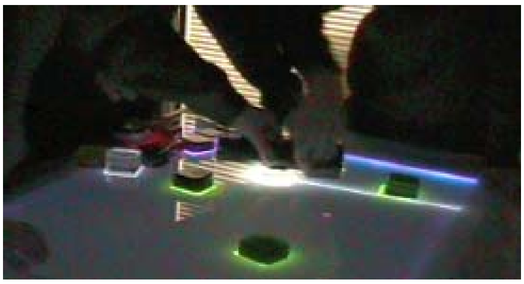

Figure 4. Three children disputing the torch

In this environment all digital effects depended on *one* physical resource (the torch) being placed on the surface (see Section The Tabletop Environment). The torch, being the source of all digital effects, was essentially a "control tool". As such it was occasionally the centre of dispute, for example, in one instance three children physically (though gently) disputed the torch (Figure 4): they had their hands placed on the object and tried to point it to different objects. These kinds of dispute usually ended with someone naturally giving up. In some groups, one child would clearly stand out as a leader and keep the torch under his control (and on his "territory", i.e., closer area of the table) most of the time, though in other groups interaction flowed very collaboratively, with a shared – rather than centralized – control of the torch. Although this feature had the potential to cause centralized control depending on the personal characteristics of users, it actually turned out to be a smooth way of implicitly enforcing collaboration through the interface (Piper et al., 2006). In the case of shy children, for example, despite their tendency to play in their own corner of the interface, they needed to get involved with the group activity to gain access to the light beam and therefore be able to produce some effect from the objects they were manipulating. Thus, this design was useful in promoting all children to be actively included in the collaborative activity. Furthermore, as interaction did not depend on possession of a physical object (i.e. the torch) itself, to engage in exploratory activity using the objects but the virtual light beam emitted from the torch, the potential for inclusive collaborative activity was enhanced.

Virtual resources in the environment (i.e. virtual beams of light) could be easily "captured" by children using physical blocks, which transmit, absorb or reflect the virtual beam. Interference here can be seen as a kind of 'control' action, where children were trying to exert, or maintain control of the digital effects from their actions, and in so doing caused interference for others actions. Sometimes this was intentional and sometimes not. For example, children very often: placed an object in between the torch and another object placed by their peer, therefore intentionally "stealing" the white beam; pushed objects out of the light pathway using another object; or simply rotated the torch. On the other hand, children could rotate a block without noticing they were depriving a peer of the light beam.

The concrete blocks themselves were sometimes taken from others, not because of interest in the particular object (as there were enough blocks available for everyone), but rather to control the current arrangement, which involved that block. This raises issues about feelings of possession. In the environment presented here, children did not stick to using a specific block – the arrangements were of more concern than the objects themselves. In one situation, a child took control not only of the torch, but also of objects being used by peers, to prevent them making changes. This was not about "possessing" the objects themselves, but about having the control of the patterns built on the table. However, despite this wish for control, our findings suggest that the dynamics of the environment contributed to a lack of attachment to personal creations (as all would easily fade), as well as the collective process of building them.

There were some situations where children would individually create configurations, but because of the 'interference' properties of the environment they automatically became involved in group activity. In one group, while building something, a boy "dictated" what the others should do so that *he* would reach *his* goal. He dragged all objects near him and pointed the torch to his territory. Another boy spent most of the session exploring the interface on his own, silently building his own arrangements, and would occasionally take objects from his peers' arrangements for his individual goals, purposely unaware of the group activity. However, as he did not always have the control of the torch, he was forced to pay attention and get involved in the group activity, even if with the only goal of getting hold of the torch at some point. In cases like these, children were using the interface "on their own, but together", i.e. although they were pursuing individual goals, the constant interference of the shared interface and the dependence of the one torch made the activity collective anyway. In other words, their effort to individually use a shared interface was prevented by a design feature. Children therefore switched between actual, explicit collaboration (dialogue and actions clearly synchronized towards a common goal) and some serendipitous collaboration, forced by the design of the interface. The only way for someone to work totally isolated would be taking control of all objects, which seems unlikely to happen (and never did in the studies presented here).

Most of the time, "stealing" concrete resources was done very smoothly, almost as if children were sharing them through mutual agreement, or "physically asking" to borrow them. For instance, sometimes children did not believe their eyes when someone else was testing an arrangement and had to *do* it themselves to check. In this case, the child would take the relevant object from their peer's hands and try out the same arrangement. In some way, such situations were part of an implicit protocol of handing resources over, according to which children would silently agree to share the objects. No situations occurred where children verbally asked for objects (by saying "give it to me"). This suggests that the physical presence of artefacts provided a way of mediating sharing (as well as constructing), without collaborators having to be verbally explicit. Awareness of others actions (as a physical form of communication) may not only facilitate fluid interaction (Hornecker et al., 2008), but also seamless sharing of physical objects as tools. This has implications for issues of inclusivity as well as providing the verbally shy with better opportunities for equal interaction.

Overall, sharing of resources happened spontaneously and contributed to the group activity. Commonly, a subset of the available objects was used collectively by the group, whose attention was focused on the arrangement produced. Children alternated control of the objects, interfering in the collective arrangement to test different hypotheses that were shared within the group, either visually or verbally.

Discussion

A key finding from the studies presented here was the 'interference' activity that occurred in different forms during collaborative interaction in the environment. It was accidental, when children did not predict the effect of their actions, or intentional, when children purposely changed arrangements, to give demonstrations or help each other out by giving instructions (both physically and verbally). Although some forms of interference can be seen as conflicting actions or clashes as mentioned by Hornecker et al. (2008), Morris et al., (2006) and Stewart et al. (1999), they do not have the negative connotation (found in the literature) within our environment, as they promoted specific kinds of collaboration, giving rise to collaborative activities that are beneficial for learning.

The tabletop environment invited parallel actions and the dynamics, which arose from those actions, provoked rapid changes in the configurations built on the table, together with high levels of interference. The global effect of local actions frequently interfered in the whole arrangement when dealing with any beam of light. As noted by Rogers et al. (2008), the technological setup had a great influence on the resulting interaction patterns. The interference-prone tabletop was particularly instrumental in provoking curiosity, drawing attention to relevant instances of the phenomena, and engendering exploratory and inquiry activity. At other times this led to the need for verbal negotiation and synchronization of actions, either to enable collective building of arrangements or to allow enough time for children to reflect on the underlying concepts. The latter case confirms findings from Stanton et al. (2002a), regarding the difficulty in finding time to reflect in synchronous interaction as opposed to a taking-turn environment; and Barron (2003), who highlights the need for learners to manage both their own effort to understand the problem and what others are doing, in such collaborative contexts. However, the visibility of everyone's actions within the environment (also reported by Stanton et al., 2002) made negotiation possible through explicit requests for slowing down or going back. Therefore, external coordination policies as suggested by Morris et al. (2006) to mediate the activity, were not needed. Instead, the children naturally found their way through a collective exploratory activity with resolution of conflicts that proved to be a constructive process, supporting the reported benefits of conflicts (Stanton & Neale, 2003). Conflicts due to shared control of resources occasionally caused longer task completion, confirming findings by Stewart et al. (1999), but provoked more reflection facing children with unexpected events (cf Price et al., 2003). In an exploratory environment in which task completion is not the main focus of the activity, longer exploration may actually be a benefit more than a problem.

Negotiation was also apparent in children's discourse through orders, suggestions, invitations to collaborate, comments on peers' actions and reporting on one's own action. This coordination of attention, said to be fundamental for joint engagement (Barron, 2003), enabled children to collectively build arrangements and test their hypotheses, answer facilitator's questions, or just explore the interface. The need for synchronization and agreement also supported constructive child-negotiated collaborative activity and promoted a collaborative process of exploration and knowledge production. Therefore, verbal interaction involved not only reporting actions (Stanton et al., 2002a) when multiple input devices are available, but also conceptual discussion and elaboration of ideas. Although physical action often surpassed conversation, children were not usually left without answers, indicating a high level of verbal reciprocity (as opposed to findings by Stanton et al. (2002a)).

Interference also played a role in the sharing and control of the system's virtual and physical resources. Digital effects (light beams) could be captured (intentionally or accidentally) by the concrete blocks, which were themselves also handed over or disputed throughout the interaction. However, this "dispute" occurred naturally and blocks were handed over allowing everyone to try out different objects themselves. Therefore, though monopolization of activities was still possible (Stanton & Neale., 2003), the characteristics of the environment made domination very unlikely, allowing the equity of participation mentioned in the literature (Stewart, 1999; Stanton et al., 2002a). The physicality and availability of input devices contributed to more balanced levels of participation, including more reticent children, and encouraged collective hypotheses' testing, as reported by Rogers et al. (2008).

As the objects did not embody representations of the users, but behaved as actual concrete blocks within the environment, they were shared with no feelings of identity or possession. Of more concern for the children were the particular arrangements, although the collaborative building process conveyed a sense of collective belonging rather than individual production. This collective ownership of productions favoured the co-construction of ideas as opposed to the co-operative individual activities that Stanton & Neale (2003) report. In our environment, children did not divide tasks, partly because the design of interface would not allow such procedure, nor did they collaborate less for having multiple input devices, as found by Stewart et al. (1999). Instead, resources were shared around a unique focus of attention and everyone had the right of interfering in the arrangements at any time (although some implicit agreement on taking turns, keeping the flow of actions reasonably sensible, respecting others' choices and allowing time for reflection was noticed).

Although synchronization was not always easily achieved and parallel actions sometimes provoked too rapid changes to allow reflection, overall interference (both through actions and their consequences and through sharing virtual and physical resources) contributed to creating a highly collaborative environment in which separate individual exploration was implicitly discouraged. Verbal and physical negotiation as well as attention to others' actions and speech emerged from the interference, leading the group through a productive process of collective exploration and knowledge construction.

Children were not formally tested on the concepts involved in the study, nor were they explicitly taught during the sessions, but their exploratory activities and post-interviews provide initial evidence of the conclusions they were drawing about light. Light reflection, being a reasonably familiar concept to the children (mainly through experience with mirrors in everyday life), was easily identified and discussed during interaction and reported in the post-interviews. On the other hand children described processes of absorption, transmission and refraction in their own words illustrating their understanding. For instance, the representation of absorption through the spectrum of colours inside the object led to statements like *"the rainbow was inside, but the green wasn't there because the green was already reflecting"*. Transmission was invariably explained as light "going through" *("it was transparent so it goes through"*); and refraction as "bending" (*"it just goes straight through it unless you've got an angle, then instead of going straight it goes down there"*). The concept of white light being made of different colours was also brought up during the interviews *("white light can separate into little parts, the colours"*), as well as the notion that an object reflects the colour you see *("so what happens if I put a white light against a blue object? Blue light will shine."*). Diffusion from rough surfaces was mentioned with enthusiasm as the virtual representation seemed to convey the correct concept *("an object with a rough surface, the light just reflects everywhere, but without it just reflects in one direction"*).

Conclusion

Recent developments in sensor based and touch screen technologies provide new tools for collaborative activity. Shared interfaces for collaborative learning pose specific challenges, and require design for activities that support productive learning through collaboration. Little work yet exists that examines the processes of collaborative interaction in co-located tangible shared interfaces and their implications for learning. A purpose-built interactive tangible tabletop environment running a software application was built to support children learning about the behaviour of light. This paper presented the findings from a study undertaken to investigate children's collaborative interaction and learning. A key finding from the studies was the different forms of "interference" and their effect on the collaborative activity. The interference-prone tabletop was particularly instrumental in provoking curiosity, drawing attention to relevant instances of the phenomena, and engendering exploratory and inquiry activity, as well as promoting verbal negotiation and synchronization of actions. The concrete input devices were shared through an implicit protocol of handing resources over and the collective nature of arrangements produced on the tabletop favoured the co-construction of ideas as opposed to co-operative individual activities. The physicality and availability of the input devices contributed to more balanced levels of participation. Overall, interference led to a highly collaborative environment, which supported collective exploration and knowledge production, although the dynamics of the interface sometimes caused too rapid changes and challenged synchronization of actions. Evidence of nascent understanding of the phenomena was noticed through children's dialogues and actions during interaction and in the post-interviews.

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Around the Table: Are Multiple-Touch Surfaces Better Than Single-Touch for Children's Collaborative Interactions?

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Abstract: This paper presents a classroom study that investigated the potential of using touch tabletop technology to support children's collaborative learning interactions. Children aged 7-10 worked in groups of three on a collaborative planning task in which they designed a seating plan for their classroom. In the single-touch condition, the tabletop surface allowed only one child to interact with the digital content at a time. In the multiple-touch condition, the children could interact with the digital content simultaneously. Results showed that touch condition did not affect the frequency or equity of interactions, but did influence the nature of children's discussion. In the multiple-touch condition, children talked more about the task; in the single-touch condition, they talked more about turn taking. We also report age and gender differences.

Introduction

It is well established that collaborative activity is beneficial to children's learning and development (Webb & Palincsar, 1996). Peer collaboration now forms a significant part of a child's classroom experience. For example, the UK national curriculum identifies the ability to collaborate effectively as a key skill that should be supported and developed throughout the primary school years (Kutnick & Rogers, 1994).

Technological support for collaborative activity in schools has traditionally been limited to the shared use of single computers (Stanton, Neale, & Bayon, 2002). However, an emerging generation of shareable interfaces are being promoted as the new technology to support collaborative learning. *Shareable interfaces* allow several people in the same place to interact on the same task using their own input device. For example, *multi-touch tabletops* are horizontal surfaces that allow multiple people to interact simultaneously through touch input. These technologies offer the potential for new ways to support and structure co-located collaborative learning activities. However, there are few studies that directly examine their effect on children's interactions and we therefore know very little about their influence on behaviour.

In this paper, we report on how a multi-touch tabletop supported a classroom design task for 7-10 year olds working in groups of three. In our analysis we examined levels of participation, the degree to which interactions were equitable and the nature of collaborative dialogue in two conditions; a multiple-touch and a single-touch condition.

Background

Definitions of what constitutes collaboration centre on the notion of mutual and joint activity. Collaboration should be a reciprocal, coordinated interaction in which ideas and perspectives are explored and exchanged (Goos, Galbraith, & Renshaw, 2002). The benefit of collaboration for learning is dependent on children's level of participation in such activity. Too often, learning benefits are impaired by inequitable participation, where the contributions of some group members dominate while others are marginalized (Barron, 2003). Participation typically refers to the level of talk and dialogue that occurs between collaborating partners (Teasley, 1995). However, in the case of computer-supported collaboration, physical action is also an important indicator of participation. For example, children might indicate agreement or disagreement through direct interaction with the interface instead of explicitly verbalizing their point of view (Kerawalla, Pearce, Yuill, Luckin & Harris, 2008; Stanton & Neale, 2003).

The unique features of multi-touch tabletops offer the potential to support collaboration in new ways (Rick, Rogers, Haig, & Yuill, 2009). For example, face-to-face, rather than shoulder-to-shoulder interactions, can promote more participation and communication between group members (Rogers & Lindley, 2004). Tabletops also provide the added benefit of a larger display area and the opportunity to organize objects spatially; this allows group members to see and be aware of each other's actions more readily (Hornecker, Marshall, Dalton, & Rogers, 2008; Nacenta, Pinelle, Stuckel, & Gutwin, 2007). In addition, touch input may be a more appealing and natural means of input as users manipulate objects directly and easily with their fingers (Shen, Everitt, & Ryall, 2003).

Children's simultaneous interactions with technology have been investigated in relation to the use of multiple mice with PC software. The findings, however, have been mixed. On the one hand simultaneous input can promote more equitable interactions between children (Stanton, et al., 2002) and higher levels of task focused participation (Inkpen, Ho-ching, Kuederle, Scott, & Shoemaker, 1999). On the other hand, it can also result in parallel working, where children work on different parts of the same task, often with limited reciprocity (Stanton & Neale, 2003). This same study found that sharing a single mouse sometimes led to good collaboration if contributions and decisions were discussed before being implemented. However, shared mouse use also led to high levels of conflict and the tendency in some groups for one child to dominate. The extent to which single input interactions are collaborative or dominated by individual children is largely dependent on individual differences between children, rather than an inherent characteristic of the technology. Age and gender differences, for example, play an important role in how children manage turn taking and contribute to collaborative interactions, particularly around technology (Abnett, Stanton, Neale, & O'Malley, 2001; Inkpen, Booth, Klawe, & Upitis, 1995).

Other studies have observed children as users of multi-touch tabletops. SIDES is a tool designed for adolescents with Aspergers Syndrome to practice effective group work (Piper, O'Brien, Morris, & Winograd, 2006) and StoryTable is a system designed to support children's storytelling activity in groups (Cappelletti, Gelmini, Pianesi, Rossi, & Zancanaro, 2004). StoryTable enforces a co-operative task structure such that children can simultaneously work on individual parts of the task but are then forced to perform crucial operations together in order to progress. Similarly SIDES encourages co-operation as adolescents have to work together to build a path by combining individually owned pieces. In a further iteration to this system, turn taking was regulated and enforced in order to ensure participation from those who were disengaged from the task and to prevent others from dominating.

In the current study, we investigated participation around a tabletop interface in a typically developing sample of primary-aged children. One potential use of multi-touch tabletops is to support *collaborative design*, where users collaborate to design an artefact. Design is an established method for promoting learning. Designing external artefacts can motivate learners (Harel & Papert, 1991). The designed artefacts can embody concrete connections to the underlying domain concepts, which learners actively engage through the design process (Kolodner, Camp, Crismond, Fasse, Gray, Holbrook, Puntambekar, & Ryan, 2003). To observe how children use a tabletop interface for collaborative design, we developed the OurSpace system, which supports children in designing a seating plan for their classroom.

We used a DiamondTouch interactive tabletop that recognizes individual user's interactions (Dietz & Leigh, 2001). The software was configured to support both a multiple-touch and a single-touch mode. Taking advantage of this flexibility allowed us to investigate the value of concurrent interactions around the tabletop to a system that requires users to take turns.

Marshall, Hornecker, Morris, Dalton, & Rogers (2008) report a study of participation around a tabletop interface for adult participants who completed a similar seating design task. They found that multiple-touch input facilitated equity of interaction compared to a single-touch condition, but had no effect on levels of verbal participation. In the current study, we wanted to examine the value of different touch conditions on children's collaborative interaction. Based on related literature, there are two competing hypotheses about which condition is most conducive to useful collaboration: (i) multiple-touch mode supports better collaboration by allowing more equitable participation at the tabletop, thus allowing everyone to interact whenever they want (Rogers et al, 2009); (ii) single-touch mode supports better collaboration as it forces more turn taking, thus increasing awareness of what each group member is doing (Hornecker, et al., 2008).

Method
A within-subjects design was used in which groups completed both the multiple-touch and single-touch conditions of the task. Each mode was undertaken in a separate session approximately 2-3 days apart. To control for order effects conditions were counterbalanced, where half the groups completed the multiple-touch condition first and half completed the single-touch condition first.

Participants
The study was conducted in two urban primary schools in the southeast of England. In total, 45 children (21 boys, 24 girls) participated in the study from three different classes (Year 3 from School A and Year 3 and 4 from School B). The Year 3 children were 7-8 years old and the Year 4 children 9-10 years old. Teachers were asked to group children on the basis of two criteria: gender and group compatibility. This resulted in 15 same-gender same-year group triads (7 boy and 8 girl groups).

OurSpace
The OurSpace software was designed to support a seating allocation task that was both meaningful to the children and challenging enough to require collaboration and compromise. A large floor plan of their actual

classroom was centered on the interactive tabletop (Figure 1). Participants (seated left, bottom, and right of the screen) used their fingers to drag students and tables onto the floor plan. When a student icon was dragged over an available table seat, the seat was highlighted and the student oriented toward that seat position (Figure 2a: Frame 1); when dropped, the student icon snapped to that seat (Figure 2a: Frame 2). Once a student was seated, that student moved along with the table; students could also be dragged out of their seats and relocated. To rotate tables, users dropped them on rotation areas at the bottom left and right of the screen (Figure 2c). When on a rotation area, a table rotated 15 degrees every 600ms, pausing for an extra cycle in the more common vertical and horizontal positions. Tables that were dropped near each other (within 5 pixels) snapped together. To emphasize the need to place students into seats, students that were dropped in the room but not on a seat showed a red halo around them (Figure 2a: Frame 3).

Before implementing the software, we conducted design iteration sessions with target users (Year 4 students at School A) using cardboard pieces and a paper floor plan (Rick, Harris, Marshall, Fleck, Yuill, & Rogers, 2009). These iterations helped demonstrate the viability of the design task to engender collaborative dialog. They also revealed the criteria that children thought were important when seating students in the classroom. For example, friendship groups, level of talkativeness and eyesight were all discussed by children as organising properties of a classroom. Some children thought it was important to seat friends together while others felt this might lead to too much chatting in class. Equally some children thought it was important to separate talkative children while others thought that talkative children should be seated together at the front of the class so that the teacher could keep an eye on them. These criteria were clearly dimensions of the classroom that children had strong opinions on and a range of beliefs about, therefore, to make the task more challenging, we integrated these into the software (Figure 2b). Friendship groups were indicated by icon colour; to simplify, there were no overlapping friendship groups. Talkative students were shown with an open mouth and speech bubble. Those with vision problems were shown with glasses. To make the task meaningful, participants were told to create a seating arrangement for the class coming in the next year; the class was fictitious, but we kept to the same number of students and tables as the current class.

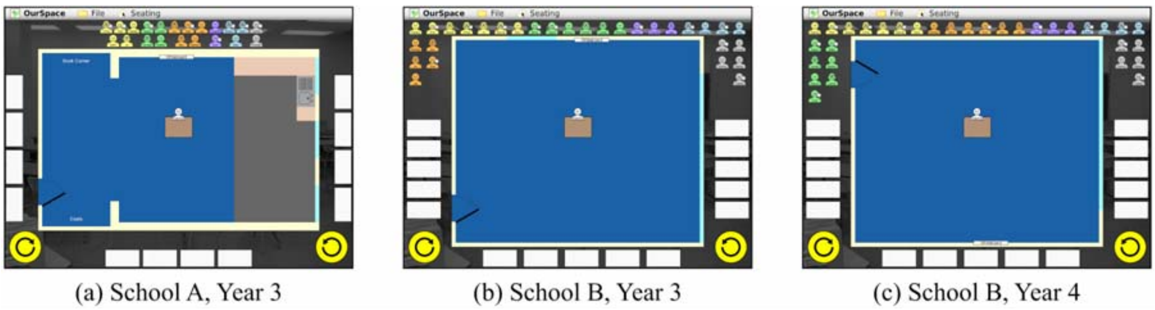

Figure 1. OurSpace classroom layouts

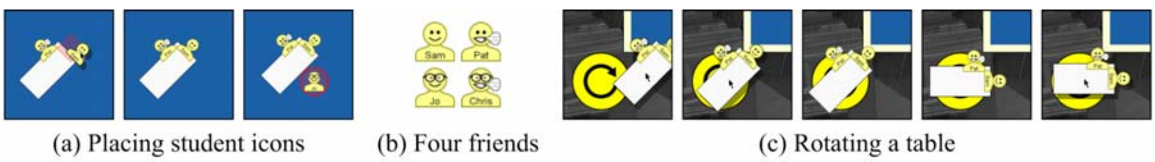

Figure 2. OurSpace feature details

Procedure

The tabletop was set up in a quiet room in the school and each group of three was taken out of class for the OurSpace sessions. At the beginning of the first session, the researchers introduced the multi-touch tabletop, the task (identifying the student characteristics, the floor plan and the idea of a seating arrangement), the application (how to move students and tables, how to attach students to tables, how to rotate tables, etc.), and the scenario (create a table and seating arrangement for next year's class). The researchers remained in the room throughout the session, but did not interact with groups while they were completing the task unless in response to specific problems with the technology. The second session began with highlighting the different mode of the tabletop (single-touch or multiple-touch, depending on condition order) and then followed an identical procedure.

Measures of collaboration

Levels of participation

Transcripts of each session were used to measure levels of v*erbal participation.* First, turns of talk were identified for each participant and then divided into individual utterances based on the application of coding categories (see below). The total number of utterances made by each participant over the course of a session was summed to give a score of their overall level of verbal participation.

Systems logs were used to measure levels of *physical participation.* This was done by calculating the rate at which children added to or changed their seating design through touches to the tabletop. Each participant's total number of touches over the course of a session was summed to give a score of their overall level of physical participation.

In order to measure the relative contribution of individuals within each group we used the *Gini Coefficient* as a measure of the *equity of participation*. The Gini Coefficient sums the deviation from equal participation for all members of a group, normalized by the maximum possible value of this deviation (Weisband, Schneider, & Connolly, 1995). Values range from 0 and 1 where a low score represents greater equity. For a set of three participation rates X_1, X_2, and X_3, it is calculated as:

$$G = \frac{3}{4}\sum_{i=1}^{N}\left|X_i - \frac{1}{3}\right|$$

Nature of discussion

As well as how much children participated in the task and the extent to which that participation was equitable within groups we were also interested in the content of the group discussions and the extent to which this varied between conditions. We iteratively developed a coding scheme for the task that categorizes talk into five broad types. Table 1 lists each talk type with an operational definition and example from the transcript. Four sessions were doubled coded by a second rater and a kappa coefficient of .88 was achieved.

Table 1. OurSpace Coding Scheme

Talk Types	Definition	Example from transcripts
Task Focused	All task focused utterances relating to the design of the seating plan.	'Lets put chatty ones near the front' 'If the chatterboxes aren't with their friends they won't chat'
Turn Taking	All utterances referring to turn taking	"It my turn next, then yours" 'Stop doing it, its my turn!'
Brief Response	Short responses to suggestions or moves	'yeah, ok' 'no, no'
Evaluation	General evaluative comments about the task	'This is hard' 'This is easy' 'I like doing this'
Other	All utterances not coded as above. These included off-task comments, questions and comments about the setup of the technology, comments to the researcher and fillers.	'Is it assembly next?' 'Why do I have to stand on the mat?' 'Is this on the internet?' 'Are we going to have another turn next week?'

Results

In the following analysis we used groups (N =15) as the unit of analysis although note that results were similar when individual data was analyzed. Group scores were calculated by summing the scores of individual group members. As there was no specific time limit on the task, the length of sessions varied considerably. As seen in Table 2 single-touch sessions, which ranged from 8.7 minutes to 23.81 minutes were on average longer than the multiple-touch sessions, which ranged from 6.28 to 22.89 minutes. Although the overall difference between touch conditions was not significant there was an interaction of touch condition with session order where multiple-touch sessions that occurred second were shorter than all other sessions ($F(1,13) = 8.36$, $p < 0.05$). We have therefore included condition order as a between subjects factor in our analysis.

Levels of participation

Verbal and physical participation

Due to differences in session lengths, we calculated the mean number of utterances per minute for each group as a proportional measure of verbal participation and the mean number of touches per minute as a proportional measure of physical participation (see Table 2). Repeated measures ANOVAs show that levels of physical participation were significantly higher in the multiple-touch condition ($F(1, 14) = 9.85$, $p < 0.01$), while levels of verbal participation did not differ significantly between touch conditions. The higher rate of touches in the multiple-touch condition is not surprising given the opportunity in this mode for working simultaneously, in contrast to the one-at-a-time restriction of the single-touch condition. We also found a negative association in the single-touch condition between verbal and physical participation ($r = -.56$, $p < 0.05$); as verbal participation increased physical participation decreased and vice versa. There was no significant relationship between participation types in the multiple-touch condition.

Table 2. Means and standard deviations for time on task, level and equity of participation

		Multiple M (SD)	**Single** M (SD)
Time on task *(minutes)*			
	Session 1	16.19 (4.4)	15.56 (5.2)
	Session 2	10.41 (3.4)	14.21 (3.4)
Level of participation *(mean utterance/touch per minute)*			
	Verbal	15.46 (6.5)	16.08 (5.1)
	Physical	92.96 (47.25)	63.18 (34.19)
Equity of participation *(Gini coefficient)*			
	Verbal	.17 (.10)	.21 (.17)
	Physical	.18 (.09)	.20 (.12)

On further investigation of between subject factors, we found that participation levels (verbal and physical) in the single-touch condition were significantly correlated with the mean age of the group (see Table 3). The positive correlation with verbal participation and the negative correlation with physical participation suggest that older children tended to talk more in the single-touch condition while younger children tend to touch more in this condition.

Equity of participation

Analysis of the *Gini Coefficients* revealed no significant difference between touch conditions in levels of verbal or physical equity. In addition, verbal equity scores were highly correlated across conditions ($r = .61$, $p < 0.05$) suggesting that individual differences between groups, in relation to verbal equity were consistent regardless of touch condition. However, verbal equity was significantly related to the age of the group again in the single-touch condition but not in the multiple-touch condition (See Table 3). The relationship indicates that the younger the group the less equitable their interaction. We also found that physical equity was different for male and female groups depending on touch condition. Figure 3 shows that boys were less equitable than girls in the single-touch condition, while girls were less equitable than boys in the multiple-touch condition; the interaction approached significance ($F(1, 13) = 4.3$, $p = 0.058$).

Table 3. Correlation of age with level and equity of participation

	Multiple		**Single**	
	Verbal	*Physical*	*Verbal*	*Physical*
Level of participation *(utterance/touch per minute)*	.42	-.35	**.65***	**-.58***
Equity of participation *(Gini Coefficient)*	-.29	.36	**-.62***	-.02

** p < 0.05*

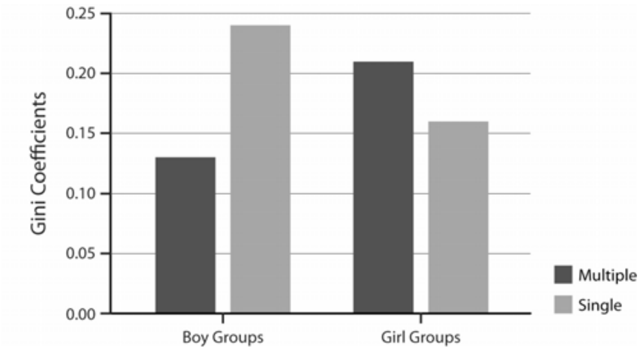

Figure 3. Physical equity by gender (lower values indicate more equitable interaction)

Nature of discussion

Figure 4 shows the proportional distribution of talk types across both conditions. In the following analysis, we focus on *task focused* and *turn taking* talk and exclude: *brief response* as it occurred equally across sessions, *evaluative* as it occurred too rarely for meaningful analysis, and *other* as it incorporated a range of behaviours not directly related to the design task. In the *other* category, off-task comments were rare across both conditions while comments relating to the technology setup were relatively frequent; children were interested in how the tabletop worked, whether their school was going to get one and related questions.

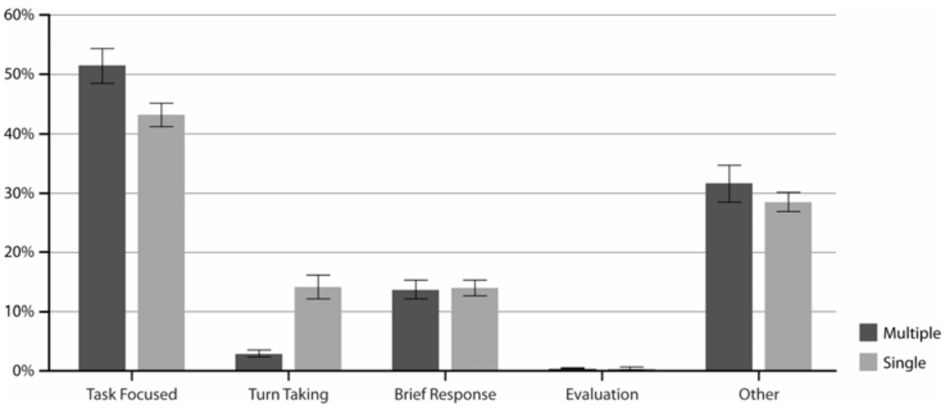

Figure 4. Proportional distribution of talk types across conditions

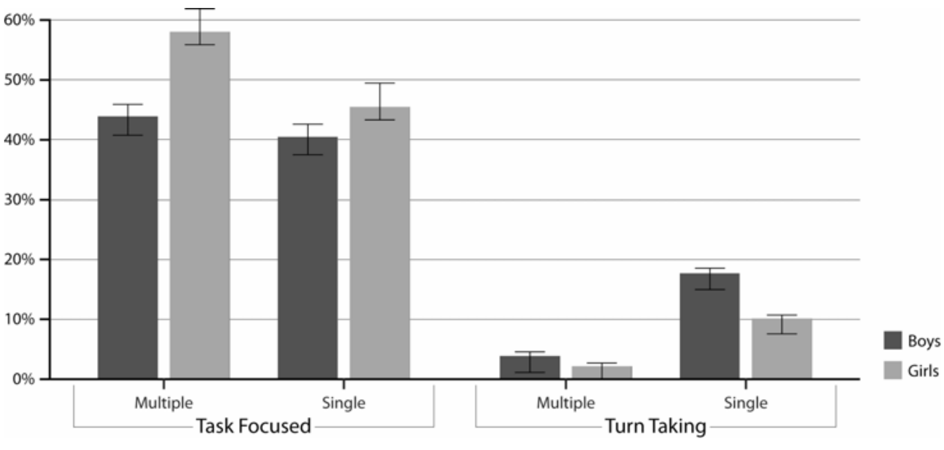

Figure 5. Task focused and turn taking talk by gender

A repeated measures MANOVA, with touch condition (multiple and single) as within subjects and talk type (task focused and turn taking) as dependent variables, revealed a significantly higher proportion of *task focused* talk in the multiple-touch condition ($F(1, 14) = 9.28$, $p < 0.01$) and a significantly higher proportion of *turn taking* talk in the single-touch condition ($F(1, 14) = 31.08$, $p < .001$). In addition, there was a negative relationship between *turn taking* and *task focused* talk in the single-touch condition ($r = -.51$, $p < 0.05$); as *turn* *taking* talk increased, *task focused* talk decreased. This relationship was not evident in the multiple-touch condition.

Analysis of between subject variables revealed no effect of age or order effect on talk type, but there was a significant gender effect. As shown in Figure 5 girls used proportionally more *task focused* talk ($F(1, 13) = 7.98$, $p < 0.05$) and boys used proportionally more *turn taking* talk ($F(1, 13) = 5.04$, $p < 0.05$) regardless of condition.

Discussion

The overall high levels of task-focused discussion we observed suggest that this task was not only engaging for children (i.e., they were motivated to achieve a good result) but was also challenging for them (i.e., due to the different constraints, there was no simple solution that satisfied all the design criteria). As a result the task elicited appropriate dialogue and discussion from our participants; elements important for learning within such a context (Yuill, Kerawalla, Pearce, Luckin & Harris, 2008). This was the case in both conditions where neither multiple- nor single-touch modes emerged as better for discussion about the task.

The degree of verbal and physical equity was also consistent across conditions. Based on previous studies with children using multiple mice (Stanton & Neale, 2003) and adults in multiple- and single-touch tabletop conditions (Marshall, et al., 2008), we had predicted that multiple-touch would enable more equity in children's verbal and physical participation. However, our results showed that overall children's interactions during this task were highly equitable across *both* touch conditions as scores tended towards zero (perfect equity). Therefore, the multiple-touch functionality of the tabletop did not result in higher levels of equity, in comparison to the enforced single-touch condition as we had predicted. This suggests that the benefits of an interactive tabletop do not depend on simultaneous input but perhaps lie in a more general quality of the form of input (i.e. touch). Marshall et al (2008) in their study with adults doing a similar design task found that multiple-touch input facilitated greater equity of physical participation, but that touch condition had no influence on levels of verbal participation. The single-touch condition in their study was implemented by using only a single conductive pad to interact with a DiamondTouch tabletop; thus, participants had to physically change location around the tabletop in order to pass control. In the study reported here, single-touch was implemented by blocking others' actions in software and therefore required no change of location. The differences between the way in which turn taking was enforced between studies adds further support to the notion that the form of the input plays a crucial role in how equitable interactions are likely to be; in our study, direct touch to the tabletop was all that was required for interaction in contrast to the change of location required in the Marshall et al (2008) study.

As well as examining levels of verbal and physical participation, we also focused our analysis on the content of discussion. Children talked more about their designs (task-focused) in the multiple-touch condition than they did in the single-touch condition. However, in the single-touch condition, talk about turn taking was more frequent and appeared to be replacing discussion about design. It is not surprising there was more turn taking talk in the single-touch condition, as children would have to negotiate how turns should be managed if all group members were to participate equally. However, we observed considerable differences between groups in children's ability to manage and regulate this type of interaction. Some group interactions were characterized by frustration and high levels of negative affect during single-touch interaction, especially when a particular child was perceived as dominating. For example:

Group1: Single-touch

Child A	*Yeah like that Beth.*
Child C	*Amy get your finger off the board!*
Child B	*It was there and you put your finger like there.*
Child C	*Beth get off! Get off!* *Beth you already had so many turns.*
Child B	*Last time you did it.*
Child C	*I think you should let Amy have a go.*
Child B	*Last time you did most of it.*
Child C	*No, not lots of it.*
Child B	*But you did though!*

Other groups were more successful at regulating turn taking during single-touch interactions. For example, some groups generated rules for the interaction and decided democratically how to manage turn taking in order that everyone had an equal opportunity for participation. For example:

Group 2: Single-touch

Child A	*No no, let's take it in turns to do it like one at a time, me or Tom first, then Jack then either me or Drew.*

Child B	*What?*
Child A	*'cause then it goes, like that (motions a circle around the group with his finger) for example or like that. (motions a circle with his finger the other way)*
Child C	*Shall I go first or you Ben?*
Child A	*Erm*
Child C	*Have a vote. Oh Joe it's not your go!*
Child A	*Ok let's let Jack go first, like that. We can take it in turns to say ideas then we can do it one at a time.*

Group 2's interaction demonstrates the kind of co-operative working that was characteristic of the single-touch condition. For example, in groups that tended to allocate rules for turn taking there was also the tendency to divide the task into subtasks and allocate responsibility for these subtasks to particular group members. This is illustrated in this second example from Group 2:

Group 2: Single-touch

Child C	*Ok, I'll do the people. Somebody does the tables, I'll do the people and somebody turns.*
Child A	*I'm doing the tables*
Child C	*Ok do you wanna turn, no, no he's doing the tables, Alex is doing the tables. (moves B's hand away)*
Child A	*Ok I'll do the people*

These extracts offer support to our second hypothesis, which predicted that single-touch would be associated with more awareness of the other group member's actions. However, the extent to which this led to co-operation or frustration and dominant behaviour was dependent on individual group characteristics.

The finding that task-focused discussion often replaced turn taking talk is illustrated by a further extract from Group 2, taken from their multiple-touch session. Here, the group were all focused on the same part of the activity and were talked together about where to seat particular students in relation to the student's attributes. Their discussion involved explicit reasoning and justifications. Compared to their talk about turns and subtasks in the single-touch condition, this interaction was more collaborative in nature.

Group 2: Multiple-touch

Child B	*OK now shall we put the people on?*
Child C	*Yeah the chatty people at the back.*
Child B	*OK.*
Child A	*But there's one with glasses and that's chatty!*
Child C	*Where?*
Child A	*There and there.*
Child B	*Then just put them at the front.*
Child C	*Well then put them still near the front because it's hard to see.*
Child A	*And they're also friends.*
Child C	*Look, no, oh yeah chatty people go on the back with their…no wouldn't they need to go on the front so the teacher can see them?*

Another important finding to emerge from this study is the importance of considering age and gender when designing for collaborative activities. We have found that differences that exist in relation to these variables seemed to be accentuated in the single-touch condition. For example, younger groups tended to engage in less dialogue and were less equitable in their verbal interactions during the single-touch condition. In addition, boys tended to talk more about turn taking than girls and were less equitable in the single-touch condition, where turn taking was necessary. It is interesting to note that these differences seemed moderated by the touch condition, as they were less evident in behaviour in the multiple-touch condition. This might be because multiple-touch provided the opportunity to work more independently; children could engage in simultaneous input without enforced awareness of other group members. The multiple-touch functionality might therefore act to mask developmental and gender related differences in which are not challenged by the constraints of the technology.

A particular strength of this study was the holistic approach we took to understanding the collaborative process. We analyzed children's physical and verbal participation, acknowledging that collaboration can occur through doing as well as talking. However, we did not underplay the importance of talk and measured both the amount of talk as well as the content of that talk. In doing this, our results suggest that tabletop working encouraged children to participate equally in both the discussion and the activity of collaborative interaction. Varying simultaneous versus one-at-a-time input influenced the nature of the discussion and allowed for the influence of important individual differences between children.

There were also a number of limitations in the findings reported here that point towards future work. First, we focused on children between the ages of 7 and 10 and found interesting age-related trends. While younger children can use interactive tabletops, their ability to use the interface and their ability to collaborate on a task is substantially different (Mansor, De Angeli, & De Bruijn, 2008). Much of the work on collaboration with multiple mice has used younger (e.g., Stanton & Neale, 2003) or older participants (Inkpen et al., 1999). It would be interesting to extend our work to both younger and older groups.

We also only focused on one kind of collaborative task – a design task with a shared integrated representation. While collaborative design is an important task, particularly in regards to learning, other tasks may elicit substantially different behaviour. Tan et al. (2008) call for a standard set of evaluation tasks to allow for comparison between different configurations of shareable interfaces, but it is unclear to what extent existing frameworks such as McGrath's task circumplex typology will be useful in classifying tasks for this new generation of tools for co-located collaboration.

Finally, we only used the DiamondTouch tabletop in the school for a short period of time and the children were excited to be able to use this new technology. Therefore, it remains to be seen to what extent findings are attributable to the novelty of the system (Rogers, Scaife, Gabrielli, Smith, & Harris, 2002). We plan to explore in future work whether our findings would extend to the situation where such technologies had become a normal part of classroom practice.

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Physical space and division of labor around a tabletop tangible simulation

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Abstract: We describe a tangible tabletop simulation, the Tinker Table, which is designed to train logistics apprentices in Switzerland. Vocational training is organized following a dual model which combines practice on the workplace and theory in the professional school. Two groups of learners were observed during an activity which consists of optimizing the layout of a warehouse. We propose a descriptive account of how the spatial position of resources and learners influences the type of manipulations which are performed by each of them.

Introduction

Recent developments in the field of Tangible User Interfaces have proposed the use of physical objects as interfaces to computer systems (Fitzmaurice, 1996; Ishii and Ullmer, 1997). These interfaces aim at bridging the gap between the physical and the digital worlds, by allowing users to interact with a computer through physical objects. Tangible User Interfaces appear to be well suited to build practice fields (Barab & Duffy, 2000) in domains implying the manipulation, arrangement, or creation of artifacts (e.g. logistics, supermarket sales clerks) and hence to establish bridges between the world of practice and theory. Among interesting properties for learning (O'Malley and Stanton-Fraser, 2004), tangible user interfaces naturally support face to face collaborative activities, which allow multiple users to interact with the system at the same time. An example is the work by Arias, Eden and Fischer (1997) on an environment supporting citizens working on an urban planning task. It allows them to define bus lines using a TUI on a map of their area. Simulations can be run, and the resulting data can be analyzed on a large vertical display next to the tabletop. In Caretta (Sugimoto, Hosoi & Hashizume, 2004), children use physical houses, factories and trees to define the layout of a town and can then observe environmental changes due to a given set of parameters. Several groups can work at the same time on connected environments that influence each other, thus encouraging discussions and negotiations among learners.

Learners are usually free to roam around these tabletop simulations, to tinker with the problem space from different locations around the table, (literally) step back to take distance to reflect about the solution. In this contribution we propose an exploration of how the physical size of the simulation environment as well as the arrangement of materials on and around the simulation table affects the type of actions which are performed by the collaborators. In line with distributed cognition theories (Hutchins, 1995), we hypothesize that the configuration of the physical environment is used as a resource to coordinate actions and influences the adoption of roles by participants. We are interested in whether and how division of labor is related to the physical position of learners and resources.

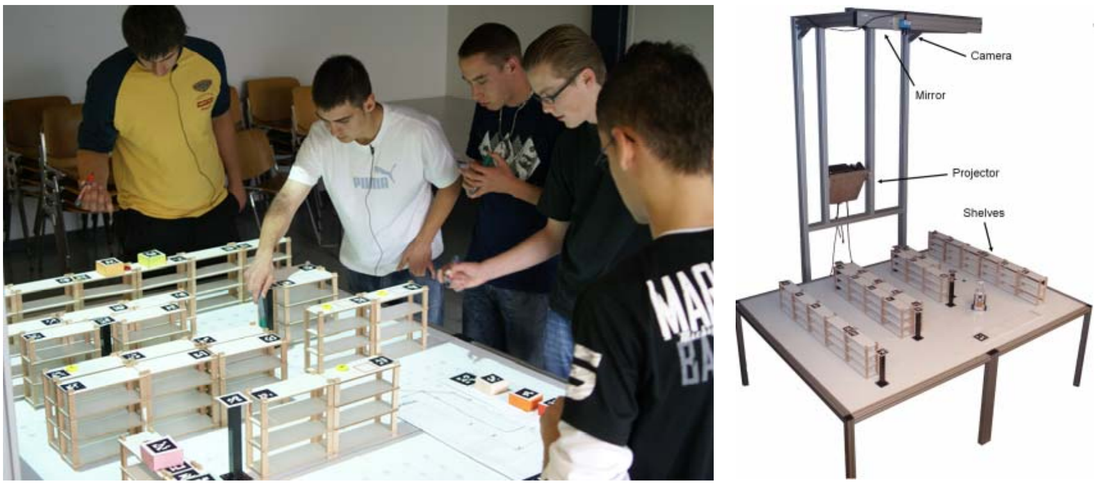

Figure 1. Apprentices working with the Tinker Table. On the left, apprentices draw and measure forklift paths on the table with whiteboard markers. On the right, positions around the table are numbered from 1 to 6. Apprentices stand around the table and are free to move.

The study concerns the Swiss apprenticeship in logistics management, a profession that involves the storage and transportation of goods (physical flow), the design of warehouses and transportation routes, as well as the management of inventories and information (information flow). During the past two years we designed and developed a tabletop tangible warehouse simulation in close collaboration with teachers from a professional school (Zufferey, Jermann and Dillenbourg, 2008). The simulation allows apprentices to build a small-scale warehouse by placing miniature shelves scaled at 1:16 on a table. The table measures 2 meter by 1.5 meter and offers enough space to accommodate the simultaneous actions of four to five participants (see **Figure 1**, left). The physical small-scale model is augmented through a video projector placed above the table. All objects (shelves, pillars, loading docks, etc.) are tagged with fiducial markers (similar to a 2 dimensional bar code) which enable a camera to track their position on the table (Fiala, 2005). The information provided by the camera about the precise position of the objects on the table in turn enables the system to project graphical representations (augmentations) on top and around the objects. The physical layout of the warehouse is used as input to configure a simulation that tests its characteristics under realistic conditions. The simulation is controlled by a paper-based interface called TinkerSheets (Zufferey, Jermann, Lucchi and Dillenbourg, 2009). Small tokens can be placed on a paper form which is recognized by the system and allows users to set parameters like the type of warehouse management (e.g. chaotic or place reservation), the number and type of forklifts, or the type of augmentation which is displayed.

Method

We follow the approach outlined by the Design-Based Research Collective (2003) which consists in testing and building working theories to make sense of a field of investigation through an iterative design and intervention cycle. We won't detail the approach here but invite the reader to consult the excellent overview by Wang and Hannafin (2005): the key points of the approach are 1) that it aims at refining both theory and practice 2) through interventions which are grounded in theories and take place in real-world settings 3) with an active participation of the participants in the design 4) through iterative cycles of analysis, design, implementation and redesign 5) by the use of an array of methods from field observations to controlled surveys 6) leading to results which are articulated to the specific context of the studies. Our investigation follows these principles rather than a series of tightly controlled laboratory studies. Therefore, at this point of the project, we do not base our quest for answers on the statistical refutation of hypotheses.

Data source

The Tinker Table has been used in class on several occasions in two different professional schools and by four teachers. In this contribution, we report observations from a session held in the beginning of 2008. Apprentices were asked to layout a warehouse so as to place as many shelves as possible on the available surface. The warehouse layout activity stems from an exercise that is usually done in class with paper and pencil. The session was run with 15 apprentices during a 2 hour session. The class was split in three groups. Group 1 was instructed to start laying out a warehouse by respecting constraints given by the teacher. Four small-scale pillars were placed on the floor of the warehouse and apprentices had to spare some space in the warehouse for an administrative room. Once group 1 finished its implementation, group 2 was challenged to do better and modify the solution obtained by the first group. Group 3 finally had to analyze the layout produced by group 2 following an ABC analysis (determines where to place different types of items depending on their frequency of movement and monetary value). We use observations from groups 1 and 2 in the analysis presented in the results section. The session was videotaped (with a camera above the table and a fixed camera which captured the general scene) and sound was recorded with ad hoc digital recorders.

Data analysis

The questions we ask ourselves and the context we work in require an exploratory approach. Data analysis was done by reviewing videotapes, and analyzing participation. We compare groups through second-by-second interaction coding. For each second and for each participant we coded whether and to whom participants were talking and whether they were acting (getting, placing or moving shelves). We also identified their position around the table by splitting the periphery of the table into 6 segments labeled from 1 to 6 (see **Figure 2**, left). The raw data obtained by this coding was then visualized in various forms to reveal the social structure of interaction. Visualizations of the division of labor are very efficient to get a sense of interaction dynamics. However, they need to be complemented with future analyses of the actual content of interaction to enable a deeper understanding of learning processes.

Action types

We distinguished four types of actions which are relevant to describe how apprentices build and simulate a warehouse layout.

- GET: consists of bringing a tangible shelf to the table. Wooden shelves were initially stored on another table 2 meters from the Tinker Table (to the right of position 6 in **Figure 2**, right).
- ADD: consists of deciding of the initial place of a tangible on the simulation canvas. Groups started with an empty table and placement was a frequent action.
- MOVE: consists of changing the position or the orientation of a tangible which is already present on the table. Several shelves might be moved at a time.
- ADJUST consists of small modifications of the position of the tangibles which are performed to 1) obtain an alley width large enough for forklifts to be able to access the shelf or 2) to ensure that the fiducial markers are well perceived by the camera. These are the most frequent actions in the sessions which we observed.

Results

Figure 2 represents the movements of the four apprentices (labeled A1 to A4) in group 1 (top) and group 2 (bottom) during a 10 and 20 minutes period respectively. It appears from the graphs that A1 mainly stayed at position 1 in both groups. In group 1, A2 and A3 were the most mobile apprentices. In group 2, A3 and A4 moved most around the table.

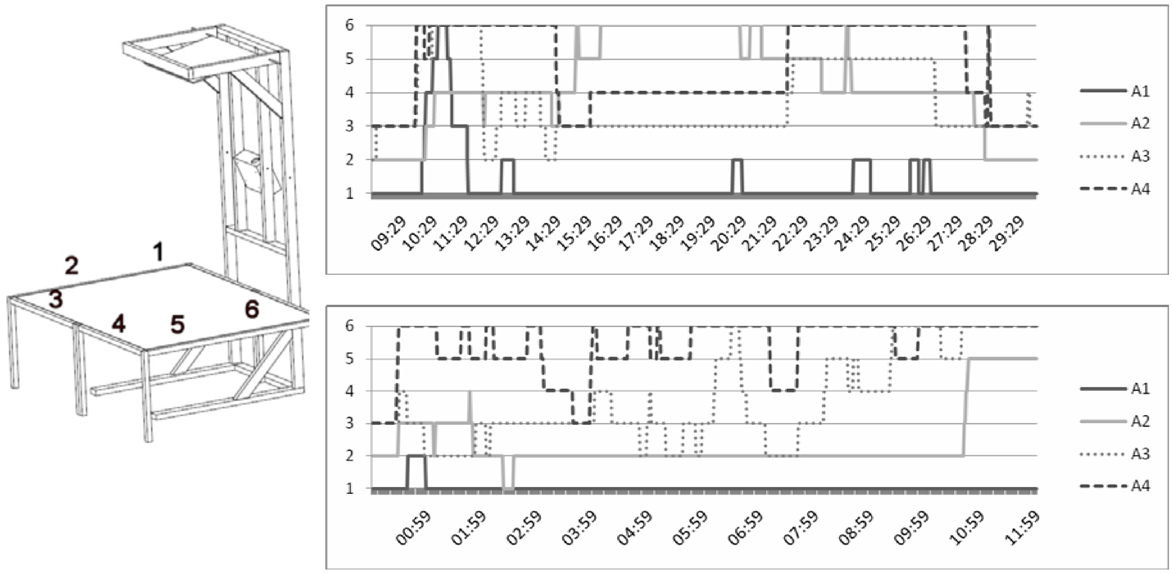

Figure 2. Timeline of apprentice's position around the table (group 1, top; group 2, bottom). Each line represents the position (1 to 6 on the ordinate) of one apprentice (labeled A1 to A4) around the table.

The three types of action (GET, ADD and MOVE) require different levels of elaboration. Bringing shelves to the table is the simplest action, but it potentially allows the actor to set the pace of the construction of the warehouse and to distribute work by handing shelves to others. Adding a shelf on the table gives the actor the power to determine the construction strategy. The placement of the first shelves had a strong impact on subsequent placements as they defined the direction of the rows and the distance between the rows of shelves. Moving shelves corresponds to doing fine adjustments or rearranging the warehouse after a diagnosis. Figure 3 shows the difference of collaboration patterns between groups 1 (left) and 2 (right).

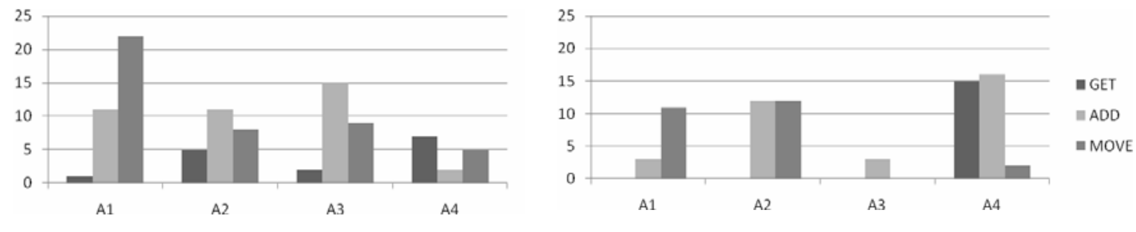

Figure 3. Distribution of action types in group 1 (left) and 2 (right). A1 to A4 correspond to the four apprentices.

In group 1, the contributions to building the warehouse were rather equilibrated: A4 and A2 both brought shelves to the table. From examining the number of ADD actions we see that A4 often handed the shelves to his peers while A2 also placed them by himself on the table. A1 did half of the MOVE actions but his peers were also involved (A1 moved the least and spent a long time adjusting the position of shelves to ensure they were recognized by the system).

In group 2, the distribution was much more uneven. One apprentice (A3) took the role of the "boss": he was giving orders to his peers but did almost no action. He only added 3 shelves and never moved one. A4 did all of the GET actions, bringing the shelves to the table and placing a significant part of them by himself (ADD actions). The movements of existing shelves were mostly taken over by A1 and A2.

Complementary analyses of the distribution of speech time confirm this difference (Figure 4). In group 1, the participation in dialogue was more or less equilibrated. After listening to the dialogue, we found that A2 took over the most reflective role while participating in the implementation as well. Typical reflections concerned evaluation of the solution (e.g. "there you can't drive with a forklift", "it's laid out like a snake") as well as the problem solving strategy (e.g. "we are not making sense here", "we should have made a sketch beforehand"). The collaboration is different in group 2 because A3 took a very dominant position and gave orders to his colleagues (e.g. "I want that shelf here", "turn this one around"). One apprentice (A1) did not participate much in the dialogue.

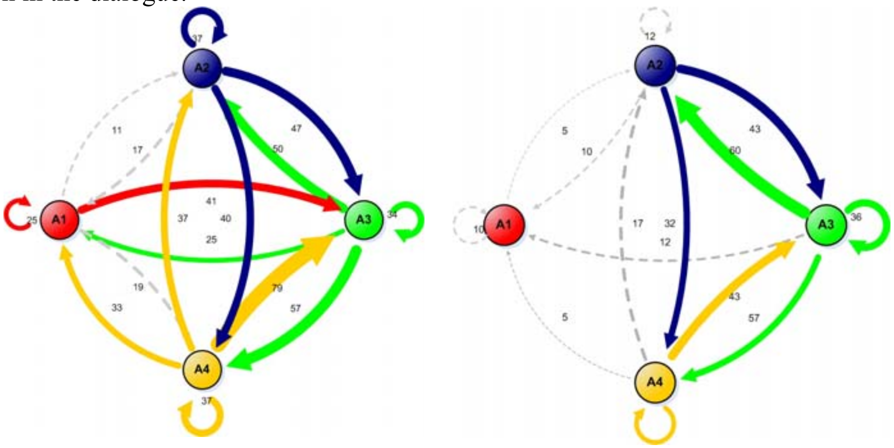

Figure 4. Collabograms for group 1 (left) and group 2 (right). The transitions show the number of seconds each apprentice spent talking. The arrows indicate whether speech was addressed to someone in particular or to all participants. The self-referencing arrows (e.g. from A4 to A4) represent speech addressed to the whole group.

To summarize our findings, we saw in group 1 that frequent movement through all locations (except location 1) was associated for A2 with an implementation activity which was also accompanied by a reflection role. In group 2, frequent movement through all locations (except location 1) was associated for A3 with the activity of directing the implementation and for A4 through places 4, 5 and 6 (closest to the shelves store) with the activity of getting and adding shelves on the table. In group both groups A1 did not move much and produced most of the move actions. In group 2, these used to be mainly adjustment actions. It appears from these two examples that the less involved apprentice takes refuge on location 1, as far as possible from where the action is.

Discussion

Our analyses have shown that there is a spontaneous division of labor among apprentices during problem-solving which is accompanied by a specific occupation of the space. This has potentially positive as well as negative effects. On the positive side, the distribution of roles allows one apprentice to take some distance and offer reflective comments (session 1, group 1). This is similar to the spontaneous division of labor which happens when two people use a computer (Miyake, 1986): one becomes the "doer" while the other becomes the "thinker". From complementary observations carried out since this study, it seems that the appearance of differentiated roles is predominant in groups of size bigger than 2 where specializations appear as a complement to the "leader" role. These specializations concerned actions which are more related to minor adjustments (removing and adjusting shelves). The negative effect of division of labor is that in each of the two cases we analyzed, one apprentice was less involved than the others. One possible explanation is that these apprentices were free-riding (Sheperd, 1993) at the expense of their colleagues' efforts. This explanation is rather unlikely as the participation of each apprentice was publicly available for inspection, and the problem was intellectually challenging.

The spatial disposition of learners and resources orients the roles adopted by learners. It is worth noting that in both groups, the least active apprentices took position on the farthest place from the shelves store. In group 2, one apprentice carried all the shelves from the shelf store to the simulation table. His occupation of location 1 gave him exclusive access to the shelves and allowed him to place half of them. The size of the simulation workspace matters as well. The large size of the table did not allow all apprentices to work simultaneously on the layout activity: the layout typically started at one end of the table (position 6) and progressed towards the other end (position 1). It is therefore not surprising that the two under-participating apprentices in position 1 did not get a chance to manipulate shelves early in the interaction.

Conclusion

The investigation of spatiality and its relation to collaboration in tangible simulations appears as a promising avenue for research. The disposition of resources and the position of learners in the environment affect the division of labor spontaneously adopted by the learners. Several challenges stay ahead of an extension of this research. First, in order to address socio-cognitive processes we need to investigate more deeply the content of conversations among apprentices. In this contribution we used a superficial coding of speech production in terms of intensity rather than quality. We nevertheless gained some useful insight from observations conducted during the collaborative sessions. The feasibility of such a content-based coding needs developments in automatic signal acquisition and filtering. The simultaneous tinkering and arguing of five apprentices around a warehouse design makes transcription and intelligibility almost impossible. In groups of 2 to 3 apprentices this problem is less important.

Concerning pedagogical design, the insight we gained through our analysis will inform the design of future lessons around the Tinker Table. To alleviate participation problems, teachers already adapted their lesson design to include specific roles for each apprentice.

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Exploring Interactional Moves in a CSCL Environment for Chinese Language Learning

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Abstract: This work analyzes the interactions of small groups of students doing collaborative learning activities in the primary classroom for learning Chinese as a second language. We take the perspective of identifying the characteristics of interactional moves as students interact and negotiate meaning in the computer-mediated collaborative learning (CSCL) environment called GroupScribbles (GS). Much work in group cognition and in interactional analysis of small groups looks at problem-solving in subjects like mathematics and science. In language learning, the task posed for collaborative activities does not focus on problem-solving, but it may be targeted towards enriching students' vocabulary and proficiency in language expression, developing their thoughts and writing through cogitating with new words, vocabulary and sentence construction. We hope the work can illuminate how students can co-construct knowledge mediated by GS representations for Chinese language learning. In the paper, we look at collaborative situations in which the group members are not seated together in the classroom, and so they have to collaborate through the GS medium.

Introduction

Chinese is a character-based language. To be literate in Chinese, one needs to know over a thousand Chinese characters (Wing, et al., 2003). In Singapore, English is the language of instruction in schools, and Chinese students learn Chinese as a second language (L2). The Singapore Ministry of Education (MOE) census reports that the most frequent reason which is cited by Singapore primary students to indicate that they do not like to learn Chinese is the great amount of Chinese words to memorize (MOE, 2004). From the perspective of linguists, the Chinese script, due to its logographic nature, is considered the most difficult script to learn by non-native learners (Shen, 2004).

Studies have been conducted concerning the level of cognitive processing and its impact on word learning and memory in logographic languages for a long time. Innovations in language education have been targeted towards a more comprehensive understanding of the development of children's capability in handling the script of Chinese, and ways of enhancing learners' structural understanding of the writing system beyond rote learning and mechanical practice (Tse, 2001, 2002). Along with developments in computers and virtual reality, explorations of the potential roles of integrative computer-assisted Chinese learning (CACL) have begun to emerge in the literature. Current research pays more attention to human-computer interaction, mainly ranging from the web-based synchronized multimedia lecture system for Chinese as second language (L2) learners (e.g., Chen & Liu, 2008) to the concrete on-line classroom teaching and learning which emphasizes Chinese course design and pedagogical frameworks. Examples of research efforts include the effects of on-line peer assessment upon Chinese writing in Taiwan primary school (Wang et al., 2007). Our literature search reveals little research in CSCL for Chinese (L2) learning. Thus, there exists a gap in research on how group students collaboratively work in on-line environment of Chinese lessons, and how group students achieve their knowledge/ideas sharing and co-construction in Chinese language learning.

In our work, we explore the use of a collaborative technology to support rapid knowledge building in the classroom. GroupScribbles (GS) 2.0 is co-developed by SRI International and Learning Sciences Lab of National Institute of Education Singapore, which enables collaborative generation, collection and aggregation of ideas through a shared space based upon individual effort and social sharing of notes in graphical and textual form. One of the key principles in the GS environment is that the notion of lightweight GS notes or contributions in which each student only can express in one word or at most few words on a small GS note. This offers the potential for learning and understanding new words and the development of thinking skills in a dynamic and rapid collaborative classroom environment for L2 learning. In the past year, we have co-designed GS lessons with the teachers, and observed over 50 classroom lessons for the subjects of science, mathematics and Chinese language learning. We noticed that the process of collaboration happened in Chinese language learning has its own characteristics, compared with collaborative activities for science and mathematics. In this paper, we analyse two episodes of GS activity applied for Chinese language learning to illustrate how students build on each other ideas in group collaborative language learning. We attempt the perspectives of identifying patterns of communication or representational practices (Medina, Suthers, & Vatrapu, 2009). These practices are joint practices developed in the emergent interaction of group members and shared by the members, practices which related to the methods for generating, manipulating and interpreting inscriptions that the group developed for handling a class of problems (Enyedy, 2005; Kozma & Russel, 2005; Roth, 2003).

Technology Support for Collaborative Learning

The GS user interface presents each user with a two-paned window. The lower pane is the user's personal work area, or "private board", with a virtual pad of fresh "scribble sheets" on which the user can draw or type (see Figure 1). The essential feature of the GS client is the combination of the private board where students can work individually and group boards or public boards where students can post the work and position it relative to others', view others' work, and take items back to the private board for further elaboration (Ng, Looi, & Chen, 2007). Students can choose anyway which they feel comfortable to express their ideas, through typing, writing by stylus or even drawing on the pad, and then post the pad onto the public board to share with others. After logging in, any students can browse all others postings posted on the public board.

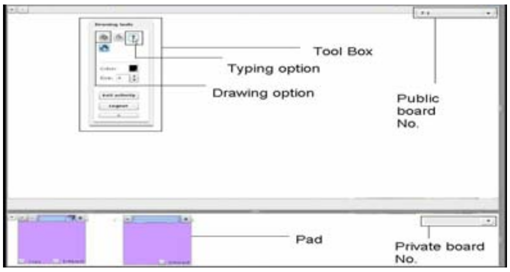


Figure 1. Interface of GS 2.0

Research Framework

A design-research approach is adopted in our school-based work in order to address complex problems in real classroom contexts in collaboration with practitioners. In this work, a higher Chinese language class in elementary grade 5 from a neighborhood primary school was involved. The 39 students in the class were divided into 10 groups. In the GS classroom each pupil was equipped with an individual Tablet-PC (TPC) with a GS client software installed.

When collecting data in classroom, 3 or more researchers observed each class and took down detailed field observation notes. Video camcorders were placed at the back of the classroom to record the overall classroom happenings. All the classroom talks were transcribed. The screen capturing software Morae 2.0 was installed on the Tablet PCs of all the computers in one group to capture the process of each student's work on the Tablet PC and their verbal talks and facial expressions. As for the analysis of the target group's interactions, researchers watched the video captured by Morae for the each members of the group, and transcribed the actions carried out by them. The actions included how pupils worked individually and collaborated on the tasks through making artifacts on GS, GS-based or verbal conversation and physical gestures etc.

We need to adopt a notation for representing flow of actions and interactions of the 4 students who are work in the same group. Stahl (2006) uses a diagram of the responses of the postings in a chat between 3 participants in a chat environment in which the postings of each participant are placed in chronological order in a column for that individual. Stahl uses solid arrows to indicate his notion of math proposal adjacency pairs and dashed arrows to indicate other kinds of responses. For our work, after analyzing several group interactions, we propose five types of responses (Looi et al., 2008) : (1) agreement on a contribution: one agrees with an idea that was suggested by another person; (2) agreement with improvement of a contribution: one comes up with a better idea building on the previous contribution; (3) disagreement on a contribution: one shows disagreement with what someone has proposed; (4) incomprehension of a contribution: one does not understand or comprehend what someone was trying to express; (5) other dependent relationship between contributions: none of the above, but there is clearly some kind of evidence of media dependencies, representational association and semantic relatedness (Suthers et al., 2007).

For the first type of response, agreement on a contribution, one agrees with the idea that was suggested from the other. Here is an example of such a response from A to B's idea:

A: What shall we do to this sick ferret?
B: How about bringing it to the vet?
A: That is a great idea!

For the second type of response, agreement with improvement of a contribution, one comes out with a better idea based on the original one from the other, besides agreeing on that. Here is the example for such a response:

A: What shall we do to this sick ferret?

B: How about bringing it to the vet?
A: That's great! Maybe after that we can ask the vet to recommend a place for the ferret to recuperate as well?

For the third type of response, disagreement on a contribution, one is disagreeing with the idea proposed by the other instead. An example for such a response will be:

A: What shall we do to this sick ferret?
B: How about bringing it to the vet?
A: I think it will be too late. The ferret is going to die soon.

For the fourth idea, incomprehension of a contribution, one is not able to understand or comprehend what the other was trying to express. Here is the example for such response:

A: What shall we do to this sick ferret?
B: This ferret needs an operation.
A: Huh? What do you mean by that?

The last type is none of the above, but there is evidence of uptake, referencing or relatedness. For example, A decides to take a bus to look for a vet, after A and B agree verbally to bring the ferret to a vet. So, the action taken by A (taking a bus to look for a vet) is a contribution that is dependent on another contribution before that (which is the verbal agreement by A and B). In the charts of Figure 3 & 4, the five types of responses are represented by different sort of arrows respectively.

Medina, Suthers and Vatrapu (2009) analyze the interaction of a small group working on mathematics problems over several days in a synchronous computer-mediated communication environment consisting of a whiteboard and a chat tool. They trace the formation, transformation, and refinement of one problem solving practice – problem decomposition—and three representational practices—inscribe first solve second, modulate perspective, and visualize decomposition. Stahl (2009) in reviewing Sfard's book says that imitation of practices is an integral part of the process of group cognition in mathematics learning. Motivated by Medina, Suthers and Vatrapu (2009), we are interested in the myriad of ways each group of students interact each time it "cogitates" about a given problem. In a knowledge building environment like Knowledge Forum and for a science discussion, we will see many interactional moves will have the nature of idea refinement, seeking to develop better conceptions of an idea. In a knowledge building environment for mathematics problem solving, we expect to see interactional moves that have the nature of making, accepting, rejecting or modifying proposals or steps to solve the problem. Our context is learning a logographic language like Chinese, and thus we are interested in the nature of interactional moves in a loosely constrained representational and collaboration environment like GroupScribbles. The contribution we hope to make in this paper is to hone the methodology to unpack process-oriented accounts of group collaboration in Chinese language learning from the perspectives of interactional moves or patterns.

GS Activities Design in Chinese Language Classes

The GS activities of Chinese Language range from learning new words/phrases, reading comprehension to writing compositions. In most of the activities, students in one group were sitting face-to-face together. However, in the group activities that being analyzed in this paper, students in the same group sat apart so that they were not able to talk verbally but could only utilize GS to communicate with each other. The purpose of this design is to find out the role of GS and interaction moves via GS by restricting face-to-face interactions. The conditions of this design serve as a boundary condition for mediating through the GS representation, and we believe that the analysis of the boundary cases can inform the more normal practice of student collaboration and mediation through both face-to-face and GS representations. For this paper, we will focus on the boundary cases. We will share two group interaction episodes which involve learning new Chinese words and constructing ideas and words around a picture frame to illuminate how students co-construct knowledge mediated by GS representations for language learning.

In Chinese language lesson on learning new words, the teacher selected 5 new Chinese words that the students were going to learn from one article of the textbook, and asked each of the ten groups in the class to choose one word to discuss and work on as a group. To facilitate students' learning, the teacher designed an organizer template and uploaded it as the background of each GS group board, for each group to collaboratively perform various tasks to learn the words. Figure 2 illustrates the template, in which the new word to be learnt has been given with the Chinese phonetics of the main character shown in the center of the left square. As shown, in this case it is "祈求" (meaning 'impetrate' or 'beseech or beg for'). The space surrounding the square is divided into 6 sections, each of which is dedicated for one task. Starting from the top left in anticlockwise order, the tasks are: 1) to explain the meaning of the word, 2) to give a few homophones of the main character of the word, 3) to give a few similar characters as the main character of the word, 4) to use the main character of the word to another word (word formation), 5) to contribute lexicon associable with the given word, and 6) to form a sentence using the words or concepts related to the words. For task 5, more space is available for the group to write down words or concepts associated with the word much like creating a concept map. After completing their own group task, the students can switch to other group boards by clicking the group number on their GS screen to see other groups' work and offer comments. The teacher monitored each group work via her computer screen although she seldom intervened so as not to interrupt the students learning within the group and from other groups. At the end of the activity, the teacher would consolidate all the group work by summarizing the strength and weakness of each group work as manifested in their GS artifacts, and would devote more time discussing common language weakness and errors with the students.

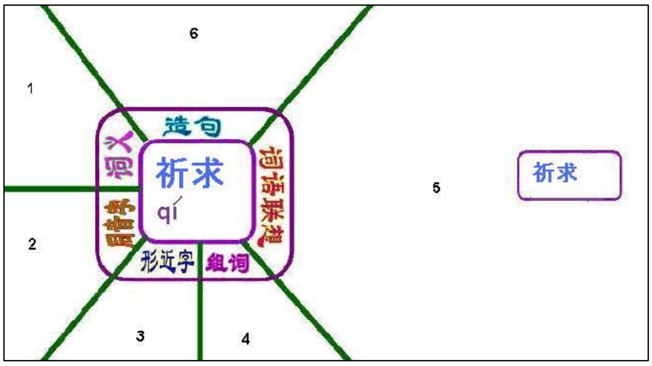


Figure 2. Template for Chinese words learning activity

The purpose of this activity is to enhance students' awareness of the character components, make them familiar with the usage of the words via making sentence, and through the interactive activity arouse students learning interest. In particular, the section on word association stimulates students who might have different vocabulary competencies to collectively co-construct, enriching their vocabulary and imagination, as well as promoting their understanding of the contexts in which the word can be used.

In another type of Chinese picture writing lesson, the students are shown a sequence of 6 picture frames, the first 5 have pictures, and the last one is blank. The 5 frames show in a comics-like way a story fragment. The 6th frame is left blank so that the students can imagine different endings to the story. Different groups are assigned to different picture frames. They are asked to think of fragments of a story line to fit the picture, and towards that, to think of associated words, concepts and ideas much like what concept mapping is. Working as a group, the students use GS to pool together their ideas to spin a good story. In guiding them, the teacher asks the students to think of an explicit storyline and to contribute as many good words as they can to describe the given picture, rather than post a complete paragraph.

The purpose of this activity design is to stimulate the students' thoughts and imaginations through interacting with each other, and to assist them to organize their final compositions well and enrich the content. They work as a group to compose the "concept map" for a picture frame in the class, and at a later lesson, each student will write their own composition based on the group-composed storyline and words to string all the 6 picture frames together. In the GS activity, while each student in the group can brainstorm, and write and post GS notes to express ideas, as there is one storyline for the group, there needs to be some coherence in the ideas which emerge when the words in the GS notes are stringed or put together. Therein lies a need for students to negotiate the storyline amongst themselves when they see potential contradictions or challenges to putting different ideas together.

Interactional Moves

In this paper, we attempt to investigate the group collaborative learning when the students were jointly doing the task in both learning new words and writing composition by sharing the interactions in the group and identifying the interactional moves.

We look at the first target group, namely Roger's group, which comprised of two moderate ability students— Roger and Sharon, and two poor ability students — John and Tina. Roger is the leader of this group. There are no high ability students in this group, but they are seen to be able to work together in harmony and their group's work is typically well-organized.

Figure 3 shows a segment of interaction of Roger's group when they were jointly complete the task about learning the word "祈求". The interactions presented are two episodes about how group members help Sharon to complete the words association occurred at the beginning and the end of the activity respectively. At the beginning of the interaction, Roger was distributing work to different members via GS as they were not able to talk to each other when seating apart. Roger posted "Sharon, ok?" in the section of word association to see if she is comfortable in doing the task (see Figure 3, R1). Sharon saw Roger's posting and replied "ok" (see Figure 3, S2) to confirm she would like to take the sub-task.

As Sharon got struck on the word association task, she posted a note to ask peers' help (see Figure 3, S3). Roger saw her posting in time and responded her with a constructive phrase "祈求上帝" (meaning 'appeal for the god') immediately (see Figure 3, R3-R4). Taking Roger's idea, Sharon re-wrote the word "上帝" by herself and posted it. Then inspired by Roger's given word, she posted another word "神明" (meaning 'the deities') which has the similar meaning of "上帝" to collocate the center word "祈求". Hence, she could continue building the words map smoothly (see Figure 3, S5-S7).

In the next segment of analysis, we come to the point when Sharon almost finished her task. Sharon posted GS note "still can think what?" for seeking peers' co-contribution (see Figure 3, S8). The weak student Tina is the first member who saw her posting, but she did not give a response to Sharon (see Figure 3, T1-T2). A few minutes later, Roger captured Sharon's note and gave her a proposal showing "hao de dong xi (Hanyu Pinyin or Chinese phonetics)" which means good stuff (see Figure 3, R5). In case his peers could not understand, he reposted it in English again (see Figure 3, R6). But it seems that he was still worried, so he wrote down "平安" (meaning 'safety') referring to "good stuff". Concurrently the other member John clicked Roger's posting "hao de dong xi" reading it. Following Roger's proposal "hao de dong xi"/"good stuff", John contributed "糖果" (meaning 'candy'), which belongs to the good things in his opinion (see Figure 3, J1). As the time was up, although Sharon had read her peers' postings, she had no time to contribute further.

From our analysis of this activity, we identify these interactional moves:

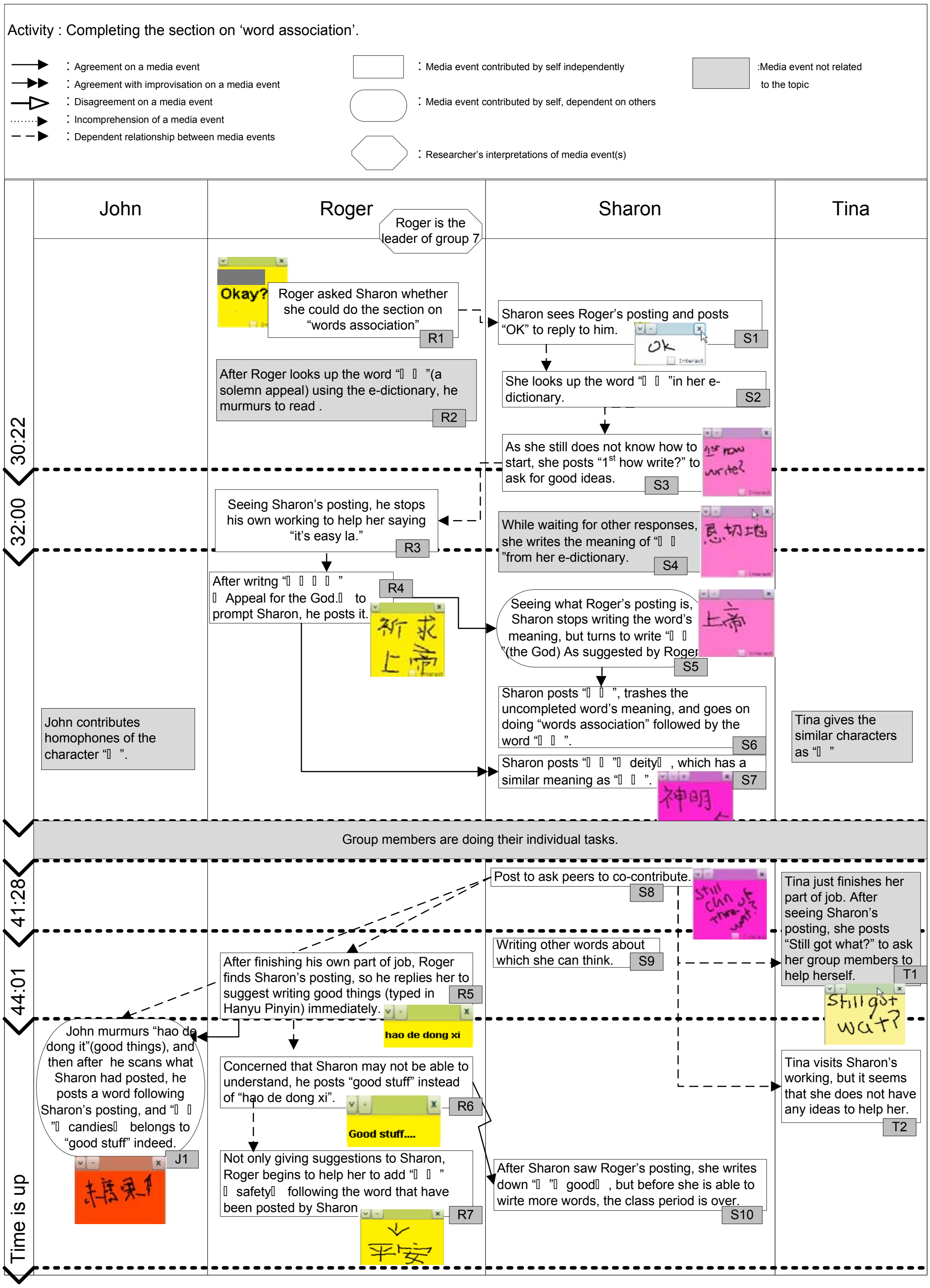
- Ask for help explicitly using a GS note (See Figure 3, S3, R3 and S8, R5-R7): This happened in a situation when a student needs ideas from the other group members to start or continue his/her work. In GS classes where the students in a group are seated together, we observe that students will ask for help verbally and their group members may pause or stop what they are doing, and respond with some help. In the case of students seated apart, they will appropriate the technology to collaborate - they sought help by using the technology, in which inscriptions are not just about the content of collaboration, but about help-seeking and coordination of the collaboration. In response to Sharon's request for help for more ideas or notes in S7, Roger responded with R5 and R6 which suggest what should be talked about, namely good stuff to impetrate, an idea, before posting an actual content contribution in R7. This interactional move seems to be a generic one in the sense we can expect such requests for help to also happen in GS lessons in other subjects like mathematics and science.
- Apart from the role of "interaction device", Chinese character representation plays an important role on Chinese Language learning due to its logographic nature. Imitate by re-writing the contribution of others, and refining it (see Figure 3, R4, S5): This practice is very much related to language learning.
- Write new words with similar meanings when cued by contributions of others (see Figure 3, R4, S7 and J1): This practice is also related to language learning.

From this short episode, we note that the uptakes comprise agreement, agreement with improvisation, and dependent relationships; there is no uptake that is interpreted as disagreement and incomprehension.

Now, we look at another episode in collaborative brainstorming and writing (see Figure 4). In the interactional moves of this group, there is no explicit request for help, and yet there is productive interaction between the students. We will look at an interaction segment which occurred between Henry and Lois (see Figure 5). This group chose picture 5 for brainstorming the storyline and the words or phrases they can use in writing up the story. The picture shows two boys in roller skates shouting and chasing after a boy who wore a cap. One might imagine a storyline in which the boy with the cap is a thief, and he is caught in the act, and hence the chase. Indeed this is what this group picked up. The episode starts when Lois posted a GS note that says "溜滑轮" (meaning 'roller skates') and "速度很快" (meaning 'high speed') to unfold the plot of the story (see Figure 4, L1). Henry followed her note by providing a posting that says "追上了小偷" (meaning 'caught up the thief') (see Figure 4, H1).

However, it seems that Lois was not quite satisfied with using Henry's posting as the next connection. Thus, she shifted it aside and put her own note that says "使主人速度比较快" (meaning 'make the speed of the owner faster') in between her posting "速度很快" and Henry's posting "追上了小偷" (see Figure 4, L2). Seeing Lois's new note, Henry posted a note with the question "谁是主人？"（meaning 'so who is the owner?'） referring to Lois's posting (see Figure 4, H2). Then Lois used the concrete names "小明和小华"

(two Chinese names) instead of “主人” (meaning ‘the owner’) which may cause confusion (see Figure 4, L4). Henry further asked Lois “怎样的速度” (meaning ‘what is the speed’), and he offered her the Chinese words for “奔跑” (meaning ‘gallop’) as a suggestion (see Figure 4, H3-H4).



Note: As students communicated bilingually, when their postings were in Chinese, English translations/meanings were provided between parentheses. But if their original postings were in English, we transcribed them verbatim including typing and grammatical errors.

Figure 3. Intra-group interaction with explicit requests for help

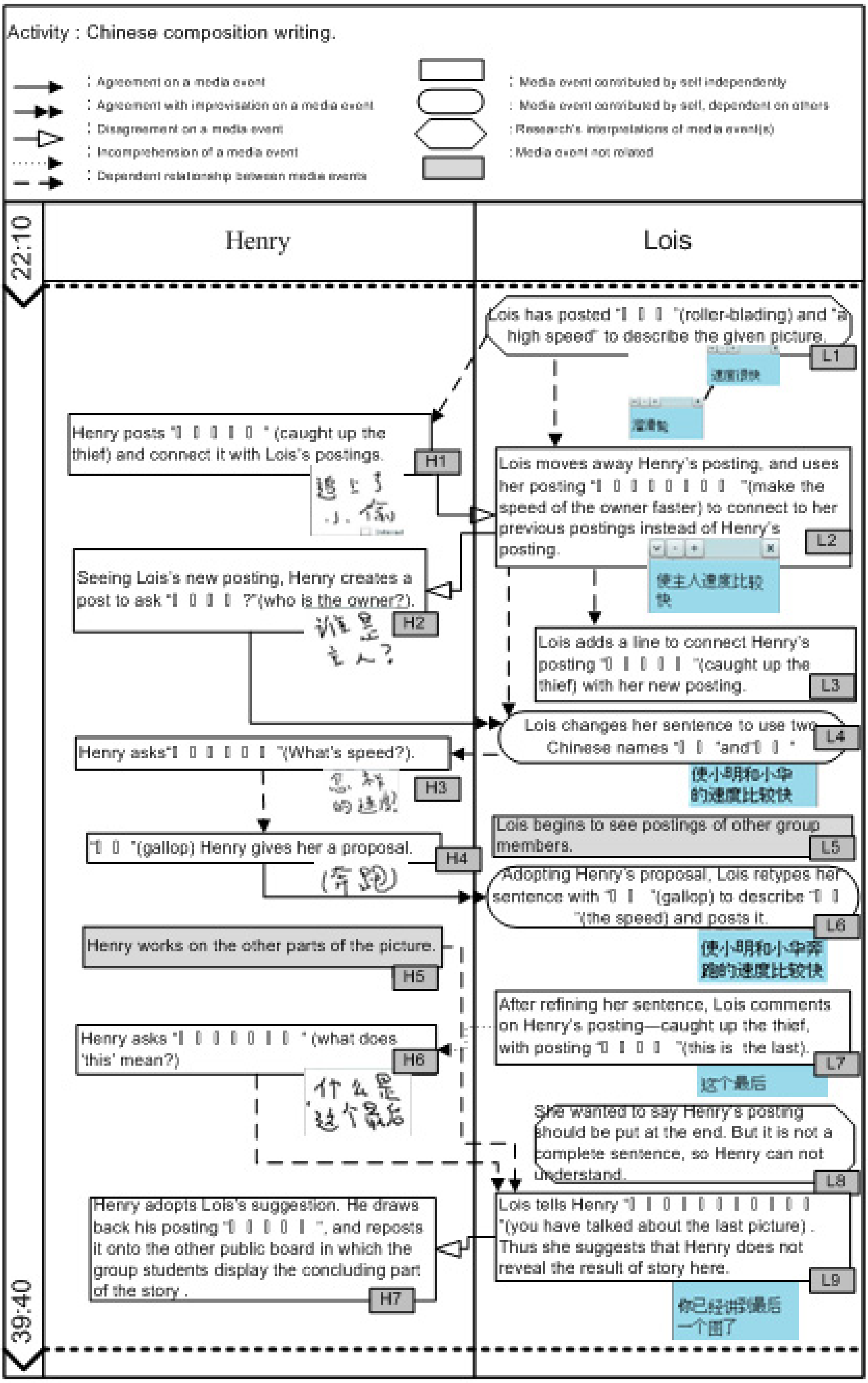


Figure 4. Intra-group interactions with peers building on each other contributions

Lois adopted it and refined her sentence again (see Figure 4, L6). Besides adopting Henry's suggestion, she made a suggestion to Henry by posting a note that says "this (should be put) at the end (of the idea sequence)" (see Figure 4, L7). In Lois's opinion, '追上了小偷' should be put the description for the concluding frame or picture 6 of the story, so as to create more suspense by putting it at the end of the story. Since Lois did not express it completely, Henry did not quite understand it. Hence, Henry asked Lois what "this" refers to (see Figure 4, H6). After receiving Lois's further explanation, he responded by moving his posting to another position (see Figure 4, H7). Figure 5 shows the final artifact of their co-constructed representations.

We identify the following interactional moves:

- See what is shared or what is newly posted, and recommends new ideas/words (H1)
- See what is on a note, and asks clarifying questions (H2)
- Seek clarification on ambiguous or unclear instructions (H6)
- Help peers polish a sentence (important for language learning) (H3-H4)
- Refining her sentence according to Henry's suggestion, Lois not only imitates but also assimilates new information (L6).

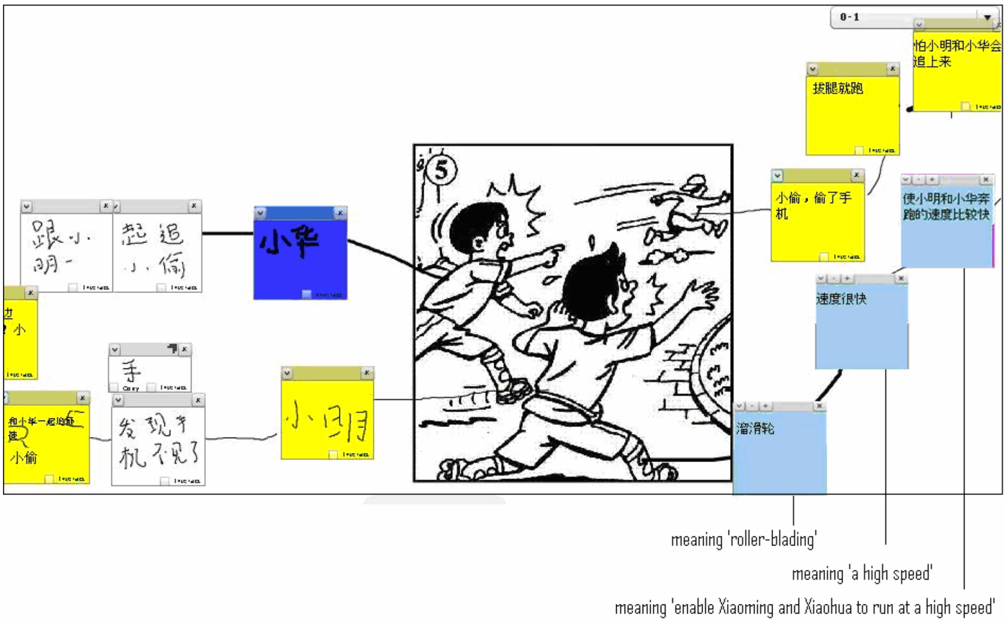


Figure 5. Parts of screenshot of the public board about Henry's group

The first three are clearly generic moves that we expect to see in GS lessons in mathematics and science, while the last two are more specific for language learning. From the perspective of second language learning, the identified practices documented that students had actually engaged in modified interactions by requesting and receiving the modified input, such as written text (Chapelle, 1998). Theory and research have suggested that the saliency of the target language input (Doughty, 1991; Sharwood, 1991) and opportunities for production of comprehensible output (Swain, 1985, 1998; Swain & Lapkin, 1995) are important for language acquisition.

This short episode has more uptakes that are interpreted as disagreement. By involving students collaborating to build up a story, it lends itself to more crashes of ideas, more contention and disagreements and more counterproposals. In the first episode, the activity is about fleshing out the different aspects of the selected words, and it lends itself to more associational idea generation.

Discussion

In both episodes, the GS environment is used in generating and sharing new ideas and knowledge related to vocabulary mastery and picture composition. The first episode happens when a student requires ideas from the other group members to start or continue his/her work. The practice has this pattern of "asking clarifying questions": Asking for help on his/her initiative, leading to imitation by re-writing from observing a response to the help, and then completing the task cued by contributions of the other members. The second episode happens when the student has represented some of his/her ideas through GS representations which become available for others to view and respond to. The practice has this pattern of "sharing your ideas and letting the others critique or build on these ideas": Peer group members on their own initiative offer help, then imitation by re-writing, and improvement or completion of the artifacts cued by contributions of others.

In the Chinese language learning context, it can be seen that no matter when help, feedback or critique is provided by group members, "imitation by re-writing" is one of the practices which seems common in language learning in these episodes. Through reading/observing the written representation from others, imitators are able to extract useful information, and refine own postings. This practice plays an important role in language learning and is the key part of the whole process of representational practices. Imitation is never a strange concept in language study. Imitation plays a role in the language acquisition process (Speidel & Nelson, 1989). Vygotsky (1930/1978, 1934/1986) noticed that children start to use new adult words before they fully understand the meaning of the words, and they learn the meaning by using the words. They begin to individualize peer or group knowledge through imitation. For L2 learning, imitation is a process of cognitive actions involving words, phrases, clauses, and sentences, which can happen in every phase of language learning. In mathematics learning, we see students imitating other group members' routines and gradually individualizing them as their own abilities.

In addition, the interactional moves are enabled by the affordances of the GS, in particular, the lightweight characteristic of GS. In web-based discussion forums or collaboration, succinct contributions shorten the response interval and avoid the phenomenon of 'interlaced communication'. In Liu and Burn's (2007) study of how to improve virtual team performance, they illustrated 'interlaced communication' as the situation in which responses are made in an interval of two or more than two postings instead of responses to the most recent posting. They asserted in this situation, a discussion topic was often terminated inexplicably instead of fully discussed. However, in GS environment, the interactional moves would not be affected adversely by 'interlaced communication'. The lightweight characteristic of GS plays the role of focusing the students' attention on the topic under discussion. In common web-based communication, there is a problem of information overload. Discussants can be so overwhelmed with messages that they ignore what others write and the conversation devolves into monologues (Moran, 1991). In the GS environment, they need not devote too much time and energy on overwriting and reading the postings of others. Moreover, it is unrealistic for primary school students learning a L2 (Chinese in this case) to do 'heavyweight' writing in classroom activities. When students attempt interpretation by writing down their responses, they can capture those insights and perceived connections so that those can be returned to, critically examined, reconsidered, and perhaps made the basis for the construction of a further sustained text of one's own (Warschauer, 1997).

Conclusion

Building on Stahl's notion of group cognition (2006) and Suthers' notion of uptakes (Suthers, et al., 2007), we propose five types of uptake responses in creating a representation and an interpretation of the transcripts in which groups of four students collaborate over the GS medium. Our analysis above shows an explanation of how two groups negotiated meaning-making in different ways. One group converged on a shared understanding of words learning and development of a storyline with accompanying articulation of the words, phrases and sentences used. One group displays explicit requests for peer responses while another group shows knowledge building on a shared workspace. This work is an initial exploration of negotiated interactional moves in the context of L2 learning in a GS environment. Future research plans include: examining their practices in a F2F situation; analyzing practices of groups across time, that is, across several sessions to study interactional moves as practiced by the group and how they evolved over time; distilling more stable patterns of interactional moves across groups and across time.

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Reducing Dominance in Multiple-Mouse Learning Activities

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Abstract: In resource-constrained classrooms in the developing world, it is common for several students to share each computer. Unfortunately, dominance behavior often naturally emerges in these situations, when one child monopolizes the mouse and keyboard. One way to mitigate this phenomenon is by providing each child with a mouse and a corresponding on-screen cursor so that everyone can interact. Though such multiple-mouse configurations reduce the possibility of total domination by one individual, they do not automatically eliminate dominance behavior completely. We propose the use of a design for small-group learning on shared computers based on enforced turn-taking in a split-screen, multiple-mouse environment. In an evaluation with 104 rural schoolchildren in India, we found that dominance behavior was indeed reduced through these design choices.

Introduction

The standard PC was designed to be used by one person at a time. In the developing world, however, shared use of computers is the norm in schools to make access more economically feasible (Patra, 2007). When groups of students share a PC, however, it is common for one dominant child to control the mouse most of the time, often resulting in the other children becoming disengaged (Pal, 2006).

Recent attempts to address these challenges have revived the concept of using multiple mice per PC (Pawar, Pal & Toyama, 2006), an idea that originated at least 16 years ago (Stewart, Bederson & Druin, 1999). Multiple mice are plugged into a single PC and each is associated with a uniquely colored cursor, allowing many children to engage simultaneously with a single PC.

A multiple-mouse configuration, however, does not necessarily eliminate the potential for dominance behavior among students sharing a PC, any more than having a public playground eliminates schoolyard bullying. Indeed, a previous study involving the use of multiple mice in computer classrooms suggested that a dominant-child phenomenon still emerges (Pawar, Pal, Gupta & Toyama, 2007). For instance, in one game that set up children to compete against one another to answer questions, the quickest child—quick either because of mastery of the subject or sheer speed of undeterred clicking—would frequently dominate play, depriving other children of the opportunity to even register what was happening on the screen.

In this paper, we address the novel problem of reducing dominance behavior in multiple-mouse learning activities. Although there are many studies of dominance behavior among groups of children (e.g., Savin-Williams, 1979), some of which apply to computer usage (Lomangino, Nicholson & Sulzby, 1999), to our knowledge this is the first time that this question has been posed within the context of multiple mice, particularly with the pragmatic approach of reducing dominance behavior through software interaction design.

Related Work

Previous work with multiple users simultaneously sharing a single computer and display with multiple input devices has been referred to as *single display groupware* (SDG) (Stewart, Bederson & Druin, 1999). Most early research in this area explored the use of two mice with open-ended tasks like drawing, or puzzle solving, rather than structured content-based learning (e.g., Stanton & Neale, 2003). In general, these studies found that using multiple mice in comparison to a single mouse, increased children's engagement and activity performance (Inkpen, Booth, Klawe & Upitis, 1995;).

In the past few years, several studies have focused on using SDG to improve shared computing in the developing world (Moraveji, Kim & Pawar, 2007). One study found that children easily understood the use of many mice at once and preferred to have their own mouse (Pawar, 2006). A later study found improved word retention after playing an English vocabulary learning game with multiple mice rather than one mouse (Pawar, Pal, Gupta & Toyama, 2007).

In addition to academic research, our design was inspired in part by trends in popular video games.

Design Process and Prototyping

We followed an iterative process of user research, design and development, employing a range of qualitative research methods and prototyping ideas at finer and finer levels of granularity. We began with a literature review and informal interviews. Prototyping then proceeded from sketches, to detailed mockups, to a working electronic prototype. The initial working prototype was tested with two groups of users in the United States: a bilingual kindergarten class and a group of eight-to-twelve-year-olds at an after-school tutoring center. This helped us arrive at a set of design decisions that formed the core elements, which we then refined during a week of informal testing and rapid prototyping in India.

Description of the Prototypes

This section provides an overview of the most complete prototype, from which variations were developed. Based on our initial research, and consideration of factors that might reduce domination, the prototypes incorporate two main design elements: Turn-taking (to allow individuals the opportunity to interact with the computer more autonomously) and a split screen (to allow concurrent activity to proceed somewhat independently in order to minimize the potential for dominance by a single child.)

The content of the game is an English-vocabulary learning exercise, which we chose because it is a simple and familiar school task. English is taught as a subject by late primary school in almost all schools in India and is generally accepted to be a desirable subject for upward mobility (Ramanathan, 1999). Moreover, rote learning of material is common in Indian state school curricula at the grade levels we studied.

We chose to design all versions of the game for four players. Given the space limitations of crowding around a single PC, we did not want to exceed five children. Because we wanted to allow for team play, four children divided into two equally-sized teams made sense. We note that other work has suggested two (Inkpen, Booth, Klawe & Upitis, 1995), three (Zurita & Nussbaum, 2007), or five (Pawar, Pal & Toyama, 2006) as "optimal."

The game begins with an orientation screen to help the players understand that each mouse is associated with one of the cursors (see Figure 1). The game activity begins once each player has clicked on a button specifically associated with her cursor color.

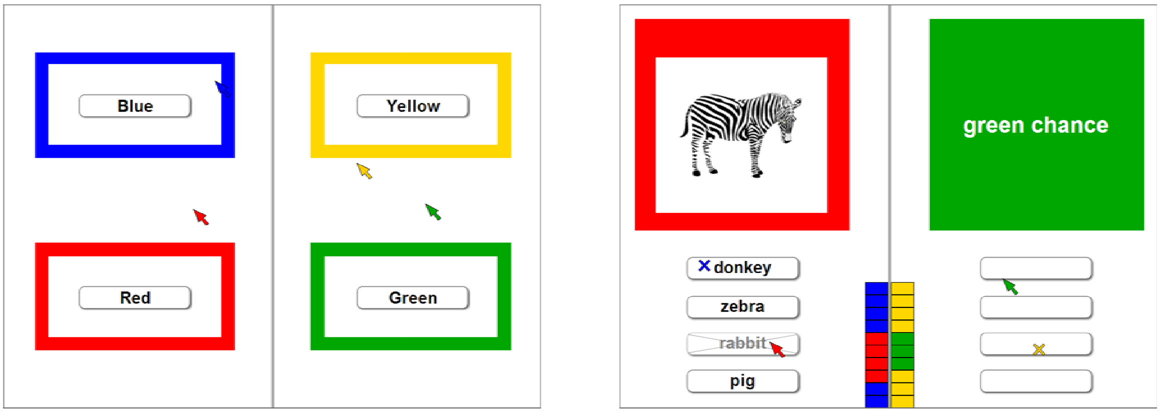

Figure 1. The orientation screen and a game in progress

The basic content of the game is an image-word matching exercise. Each question consists of an image and four buttons labeled with English words. The images and vocabulary list were borrowed from a previous study with the same population and were a good balance of familiar and new words for the target users (Pawar, Pal, Gupta & Toyama, 2007). Two questions appear simultaneously, one for each side of the screen, and the players divide into teams of two. The software then alternates turns between players within a team for every other question, and only the player whose turn it is can click on answers and get feedback.

When a user clicks on an incorrect answer, the button turns gray and the word is crossed out. When a question is answered correctly, the user is awarded points. The point scheme was designed to provide an incentive for users to answer carefully, rather than randomly clicking on buttons. Four points are awarded for a correct answer on the first attempt, three points for a correct answer on the second attempt and so on. The point bars are colored with the cursor color of the player who correctly answered the question so that each user can see how she contributed to the team's success. The goal of the game is to build the stack of points to reach the top of the screen.

Once a question is answered correctly a new question loads and a voice pronounces the word as an additional cue to the players. To help differentiate the audio cues, all sounds for players on the left side are panned to the left stereo channel and vice versa. In addition, we recorded the word cues for the left side in a female voice and the cues for the right side in a male voice to further help avoid confusion.

Notable Design Changes in the Field

The greatest challenge was making players aware that the game operated in a turn-taking mode. In early versions of the game, players would continue to click when it was not their turn, despite multiple cues to indicate the turn. We eventually realized the cues were too subtle amidst the excitement of game play.

We solved this problem through three changes to the turn cueing. First, instead of having a small colored box with a message to indicate the turn, we made the colored box much bigger and wrapped it around the entire image, right where users were most likely to look for a new question. Second, we made the non-active player's cursor smaller and changed it to an X shape rather than a pointer. (We considered eliminating the cursors of non-active players altogether, but noticed that players who understood turn-taking often helped their teammates by pointing with their own cursors to suggest answers when it was not their turn.) Third, rather than immediately loading a new question between turns so that users had to simultaneously process a new question and a message about whose turn it was, we separated these into two distinct steps by adding a brief interval between questions in which only an announcement of the new player's turn appeared.

Once children understood turn-taking, we found that they often uttered phrases such as "it's my chance" or "it's Red's chance." Discussion later revealed that "chance" is the term by professional commentators in cricket, perhaps the most popular sport in India. Consequently, we localized the interface to use "chance" wherever "turn" was used previously.

Field Visit

We tested our prototype games with target users during two weeks of fieldwork in India, where we visited a total of six state schools in and around Bangalore. In the first week we visited three state primary schools, meeting with small groups of boys and girls of primary school age, familiarizing ourselves with representative test sites and qualitatively observing children's play and reactions to the game. These sessions provided initial confirmation that the split screen and turn-taking made an observable difference in children's play patterns and their articulated responses to the games. Consequently, we decided to proceed with a focus on these elements. Based on observations during the first week, we completed a final round of design improvements (see Notable Design Changes in the Field, above) and developed a standard protocol for our evaluative study.

Evaluative Study

We conducted the evaluative study during our second week in the field, with 64 children in three schools, one in Bangalore and two in outlying villages. For the evaluative study, we defined a set of four game versions to be played by every group. This set was a stepped series in which each variation adds one design element that was not present in the previous one: split screen, one mouse per child, and turn taking. Adding one of these elements in each version made it possible to observe the effects of each independently. Table 1 compares the four game versions.

Table 1. Game Versions in the Evaluative Study

Game	*Split Screen*	*Number of Mice*	*Turn-Taking*
One-mouse game	No	One mouse, shared by four players	No
Two-mouse game	Yes	Two mice, one for each two-player team	No
Four-mouse game	Yes	Four mice, one per child	No
Turn-taking game	Yes	Four mice, one per child	Yes

The final set of observations included 16 groups of four children each. There were ten groups of all girls and six groups of all boys, all between the ages of 10 and 14. Each group session lasted approximately 30 minutes. The children played each of the four game versions twice in a row. The presentation order was counterbalanced, so that each group of children played the four versions in a different, randomly chosen order. Data collection included video recording, automated logging of question answering, and structured note taking. In the notes, we recorded the positions taken by the children around the screen, which child used the mouse at what time, and when control of the mouse passed between children.

Field Observations

We draw upon both qualitative and quantitative findings to characterize the effects of the split screen, having one mouse per child and turn taking on domination and participation in game play. We have organized these observations around four aspects of the game experience: mouse control, question presentation and answering, shared participation and qualitative observations.

Mouse Control

In games where there were fewer mice provided than players, one child often dominated play by exclusively controlling the mouse. In 20 out of the 32 one-mouse games played, one child controlled the mouse the whole time. In half the two-mouse games one child controlled the team's mouse throughout the game. In every one of these cases, control passed from one child to another child only between games rather than during them. Thus a dominant child would typically wrest and not relinquish control once he or she had it.

Splitting the screen into two activity areas had the potential to reduce the incidence of dominance through mouse control, by creating more, concurrent opportunities to answer questions. However, this design also introduced a risk: it might be more difficult for children to concentrate on their own activities in the game. As we show in the next section, this proved not to be an issue.

Question Presentation and Answering

We expected that if the split screen and teams introduced difficulties for children, we would see this reflected in either demonstrated confusion during the game or reduced numbers of questions seen and answered per group. We extracted data from the game logs on the number of questions answered collectively by the four children during each game. Comparing the four game variations, we see that the split-screen game variations approximately doubled the amount of content displayed per game. Qualitatively, we observed very few instances of confusion.

In all four variations, the game ends whenever 32 points are earned. Consequently, the number of questions answered during a game varies. When the screen is split into two queues of content and children play in teams—as in the two-mouse, four-mouse and turn-taking games—more questions can be displayed and answered. Table 2 shows the comparison.

Table 2. Total questions answered per game (N = 32 for each variation)

	One-Mouse	Two-Mouse	Four-Mouse	Turn-Taking
Mean	8.9	14.6	16.4	15.7
Standard Deviation	1.0	2.8	2.9	3.5

Looking at the average game durations for each variation (Table 3), note that the one-, two-, and four-mouse games took approximately the same amount of time, indicating that teams of two children correctly answered questions at the same pace as entire groups of four children.

Table 3. Game duration in seconds (N = 32 for each variation).

	One-Mouse	Two-Mouse	Four-Mouse	Turn-Taking
Mean	34.6	33.1	35.8	53.2
Standard Deviation	9.6	8.0	11.7	11.7

Shared Participation

Dominance by any one child in the game was reduced to the extent that multiple children participated actively. Compared to the one-mouse game, we found that for the other three games there was much greater participation by all the children in any group. In 22 of the 32 four-mouse games played, every child in the group answered at least one question correctly. Degree of domination in the four-mouse and turn-taking games was compared by measuring the differences in number of questions answered among the four group members or (in cases of team play) the pair of team members. In the four-mouse game, disparate levels of question-answering activity demonstrate that when two teammates raced to answer every question, in most cases one teammate dominated, answering the lion's share. Game log analysis of question answering in four-mouse games shows that in the average case, one teammate answered 80% of the questions put to the team, while the other answered 20%.

Adding computer-controlled turn-taking equalized teammates' participation. In an average team performance in the turn-taking game, question answering was almost evenly divided between teammates. In summary, the split screen and the use of one mouse per child reduced domination mechanically, through more mice and more opportunities to answer, while turn taking reduced it programmatically by providing exclusive opportunities for each child to answer.

Qualitative Observations

Qualitative data were gathered through structured note taking and analysis of video documentation. While limited resources precluded a full translation and content analysis of the video, limited translation provided some sense of children's exchanges. Our most notable observations concerned verbal and visual interaction among children playing together, and attitudes about group interaction expressed in post-game interviews.

Verbal Interaction: There were broadly two types of verbal exchange within groups. The first related to control of the mouse and occurred before the game started. The second type, typically occurring during game play, related to game content and what to answer. In exchanges about mouse control, the dominant child often reproached another player who attempted to get mouse control at the start of a game, causing her to give up the mouse. The exchanges during play were more varied in tone and purpose, ranging from collaboration (“Up, up, now click!”) to conflict (“You be quiet, I knew three!”). Several children expressed dislike for these conflicts, explaining that this was why they preferred to play with a mouse for each. As one child put it, “"If there's one mouse we will put it to this side or… to that side or snatch it. If there are four mice we all can share equally.”

Visual Interaction: Children were visually very expressive and often used pointing instead of, or along with speaking to indicate answers. We found that children would effectively point only at their own side of the screen, while virtually ignoring the other side of the screen, with the exception of the score display in the center.

Attitudes Toward Collaboration: In contextual interviews, most children expressed a positive view of the collaborative possibilities of the games. When asked what they would do if they knew the answer but someone else had the mouse, children routinely responded, “I will tell him the answer” or “I will teach him [or her].” Potential “telling” behaviors were observed less frequently than these responses would suggest. In one-mouse games, one child typically overwhelmed all the others in advising and cueing the clicks of the child with the mouse. In split-screen games, “telling” behaviors such as talking and pointing occurred most often between teammates and rarely between children on different teams. This suggests that competition encouraged teammates to collaborate or at least communicate.

Conclusions and Future Work

We found that our iterative design process was helpful in designing a system that adequately dealt with dominance issues. Our research offers early evidence that split-screen interfaces and turn taking have the potential to reduce dominance behaviors in small-group, co-located computer-based learning activities.

Anticipating future applications of this technology, we see the approaches of dividing the screen and automating turn-taking as potential design patterns for multiple-mouse, educational computing. We propose further design projects to validate these patterns and discover new and complementary ones (Borchers, 2001). This work would include applying these designs to more complex educational content. In addition, further evaluation is needed to determine what learning benefits, such as content retention or enhanced positive interdependence among the group, can be gained through the design approaches we have introduced.

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Distributed Weather Net: Wireless Sensor Network Supported Inquiry-Based Learning

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Abstract: In 2004, a city-wide weather wireless sensor network, Taipei Weather Inquiry-Based Learning Network, composed of sixty school-based weather sensor nodes and a centralized weather archive server was established to facilitate students having weather science inquiry-based learning. The network covers the whole Taipei City, collects the city's weather status, and opens the weather data to the general public. A series of annual weather inquiry-based learning tournaments was held since 2006 to engage the students to use the network's resource. Until now, there have been 171 registered teams which include 447 grade 4-9 students and 220 teachers involved in it. The study of the tournaments data indicated that the usability of the network was satisfied.

Introduction

Today, memorizing factual knowledge, repeating answer, or listening to lecture is not the most important issue in learning. Instead, high-level thinking skills, such as inquiring, exploring, proposing question, or finding solution independently, are the major topics for students to face the challenging new world. Science learning is essentially a question-driven, open-ended process and that students must have personal experience with scientific inquiry to understand the fundamental aspect of science (Linn, Songer & Eylon, 1996). Inquiry-based learning (IBL) provides valuable opportunities for students to improve their understanding of both science content and scientific practices (Edelson, Gordin & Pea, 1999), and plays fundamental role in schooling (Krajcik *et al*., 1998). The importance of inquiry ability as well as IBL is wildly recognized (White & Fredriksen, 1998). However, compare with traditional science learning approaches, having IBL needs more logistical supports and represents a number of significant challenges which used to discourage teachers and students. Novel technology provides traditional IBL new opportunities. Mobile sensor technology has figured out the possibility that our living environment will be embedded with a lot of sensors. These sensors can be connected as a wireless sensor network (WSN). A WSN consists of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions (Akyildiz *et al*., 2002). In this study, a distributed weather WSN was built to automatically log the weather status in Taipei City. Sixty schools were involved in the distributed weather WSN project. Each district of Taipei City was allocated at least three wireless weather sensor nodes. More weather sensor nodes were deployed in special geographical spaces, such as mountain areas or river regions, for gathering detailed weather data. The distributed weather WSN is an open Taipei City weather archive and can facilitate students to have IBL with real and instant data, no geographic constrain, effect and task oriented learning activities, and a student-centered environment. Based on the distributed weather sensor network, the research questions that guide this study are: (1) Can the distributed weather WSN help students in IBL? (2) Is the distributed weather WSN usability satisfied?

TWIN: Taipei Weather Inquiry-Based Learning Network

Taipei Weather Inquiry-Based Learning Network (TWIN) is a city-wide WSN. The goal of TWIN is to establish a distributed wireless weather sensor network in whole Taipei City and to promote IBL activities on it. The TWIN project was initiated in December, 2003. Taipei City government established thirty wireless weather sensor nodes in thirty schools in 2003, and then added the other thirty nodes in another thirty schools in 2004. The sixty weather sensor nodes were distributed in whole Taipei City, and connected by a centralized archive server. The instant weather data around the weather sensor node is collected every five minutes and wirelessly transferred to the TWIN server (see Figure 1). The TWIN website opens to the general public (see Figure 2); users who are interested in using the data for IBL can access the database freely via the Internet. The website provides not only the instant weather status, but also the historical weather data of all nodes. The time interval of historical data can be five minutes, an hour, a week, or a month. Furthermore, the demand weather data can be downloaded in Excel file format for further processing.

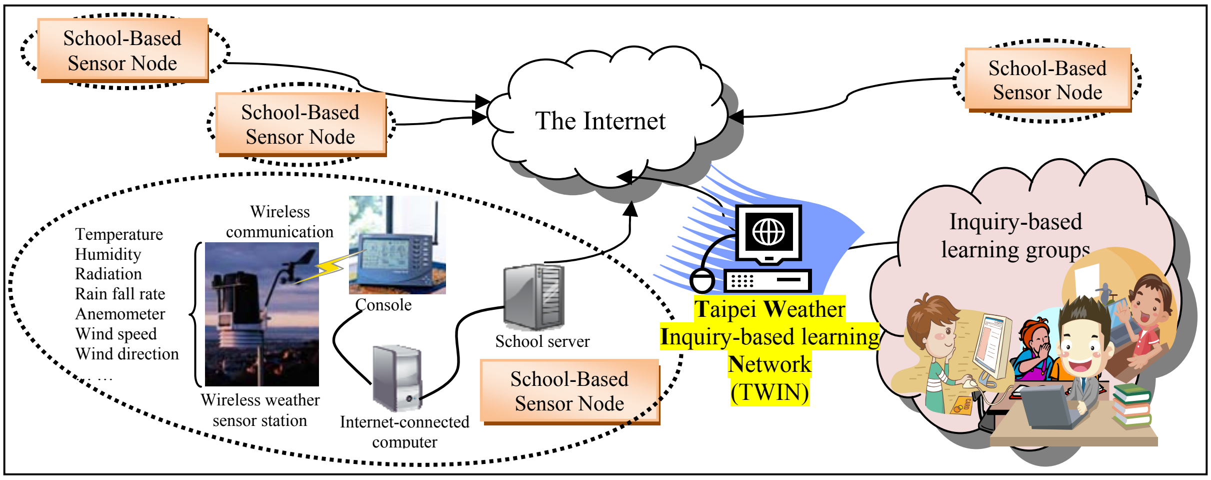


Figure 1. Taipei Weather Inquiry-Based Learning Network Architecture.

School-Based Weather Sensor Node

A school-based weather sensor node of TWIN comprises with a wireless weather sensor station, a data receiving console connected to an Internet-connected computer, and a school server. The weather school server displays instant weather status in both numerical and graphical type (see Figure 2). The weather sensor device used on TWIN is a commercial component named Vantage Pro. The device can detect temperature, humidity, barometer, UV radiation, rainfall rate, wind direction, wind speed and so on. Each weather sensor station is equipped with a solar power system, a battery, and a wireless module that enable the station to work twenty-four hours a day, seven days a week, independently. The weather data measured by the sensor station will be automatically and wirelessly transmitted to the console to generate calculated data, such as dew point, wind chill temperature, temperature-humidity-wind (THW) index, and heat index.

Figure 2. Instant Weather Data on Taipei Weather Inquiry-Based Learning Network.

The Potential of Applying Wireless Sensor Network in Inquiry-Based Learning

IBL approach has many benefits for students' learning, while novel technology, such as mobile, wireless, ad-hoc network, and sensors, can extend the usability and accessibility of IBL, and make the students' learning more effective and convenient. The advantages that TWIN can contribute to IBL are:

- Real and instant data: TWIN provides real and instant weather data of Taipei City where the students live in and relevant to. These data are logged and preliminary analyzed automatically.
- Geographic free explorative environment: TWIN, a city-wide WSN, covers the city, collects the weather status, and provides the data to the general public. The students can access and explore these open data easily via the Internet.
- Effect and task oriented: The students who participated in the TWIN project spent less time in collecting raw data, but more in studying, applying, and analyzing data, as well as developing higher order thinking strategies.
- Facilitating collaborative learning: TWIN is a rich weather data platform. Single student is not easy to handle the data individually. TWIN plays a coordinated platform for the students to have IBL. All the students are requested to form a team to explore the data collaboratively.

- Digital archive: TWIN is an automatically operating system. Since 2004, the system has been collecting and archiving the whole Taipei City weather data, and providing these data to the general public.

Inquiry Activities Design

Solely providing an exploring environment to students is not sufficient for practicing IBL approach (Chang, Sung & Lee, 2003). For facilitating the students familiarizing and performing a complete IBL activity, a four-phase inquiry flow was applied to guide the students' inquiry learning activity. Corresponding to the four-phase inquiry flow, four worksheets were designed to facilitate the interactions of the team members (see Table 1). The students were given one worksheet per week to complete their IBL process.

Table 1: Four-phase inquiry worksheets.

Worksheet I: Questioning phase 1. Finding inquiry topic. 2. Related questions following the topic. 3. The final inquiry problem. 4. Why was this problem selected as the inquiry problem? 5. Possible solutions to the problem. 6. Difficulties encountered in this phase.	*Worksheet II*: Planning phase 1. Revise the previous worksheet if needed, and list the reasons. 2. List the data items to be collected and explain the relationships between the data and the proposed items. 3. The final data log items selected. The log data time period and reasons. 4. Sources of the data. 5. How can these data sources be used? 6. Difficulties encountered in this phase.
Worksheet III: Analyzing phase 1. Revise the previous worksheet if needed, and list the reasons. 2. During the inquiry process, how much data are logged, and what is the quantity. 3. Convert the logged data to graphics. 4. List the patterns according to the logged data. 5. Difficulties encountered in this phase.	*Worksheet IV*: Interpreting phase 1. Revise the previous worksheet if needed, and list the reasons. 2. According to the data and graphics provided, can the questions be answered? 3. According to the data, graphics, and proposed questions, what evidence is available? 4. Do the findings support the assumptions listed in worksheet I? Why? 5. Do these findings support the questions listed in worksheet I? Why? 6. Difficulties encountered in this phase.

Questioning Phase

The goal in this phase is to encourage the students finding a problem they are interested in. To facilitate the students forming their inquiry problem, four anchored topics are designed to trigger the students' discussions. They are: (1) choose a physical area in Taipei City, and study the dry and humidity data of the area; (2) choose two different topographies in Taipei City, and study the humidity data; (3) study the hottest or coldest area in Taipei City; (4) study the most rainfall area in Taipei City. The students can find their own topic if they are not interested in the four anchored topics. These four anchored topics are applied to help students in squeezing their ideas and then forming their inquiry problem. The team members are encouraged to have literacy reading, gathering ideas, and brainstorming in this phase. The worksheet I listed in Table 1 is given to the students and each team is requested to complete it in one week.

Planning Phase

After having their own inquiry problem in the first phase, each team is required to generate a plan for solving their problem in the second phase. Team members can have group discussions and make assumptions on the problems. They can also preliminary check the databases on TWIN to help generating hypothesis. This stage requests the students to decide the data items, quantity of data, and types of statistical graphs needed for solving their problem. With these, each team can then divide the works to subtasks and dispatch to every member. The worksheet II listed in Table 1 is given to the students and each team is requested to complete it in one week.

Analyzing Phase

In this phase, the students have their assumptions and hypothesis in mind, and are ready to find out their answers. The students are required and facilitated to find some data and evidences on TWIN to support their hypothesis. The students need to explore the data retrieved from TWIN, and filter out the unrelated data of their inquiry problem. After the first and second phases, the students had more concrete ideas about how to use

TWIN and what question they were interested in. Following the two phases, the third phase is to encourage the students finding data, evidences, and statistic results from TWIN to support their assumption and hypothesis proposed in the second phase. The students need to have team works, study the data on TWIN, and use some tools, such as Excel, to calculate the weather data and draw statistical graphs. The worksheet III is given to the students in this phase. All the teams are required to fill out and upload the finished worksheet in one week. The students, of course, can back to the previous phase if they find some cues that don't support their assumptions or hypotheses.

Interpreting Phase

In the final phase, the students have finished their inquiry process, and are asked to verify their results. They have to demonstrate their findings in concrete numbers, graphs, and tables. Some methods, such as analyzing data, group discussion, and writing reports, are applied in this phase. Each team can verify their findings with the original hypothesis and then make some conclusions and discussions. Students have to fill out the worksheet IV in one week.

Preliminary Study

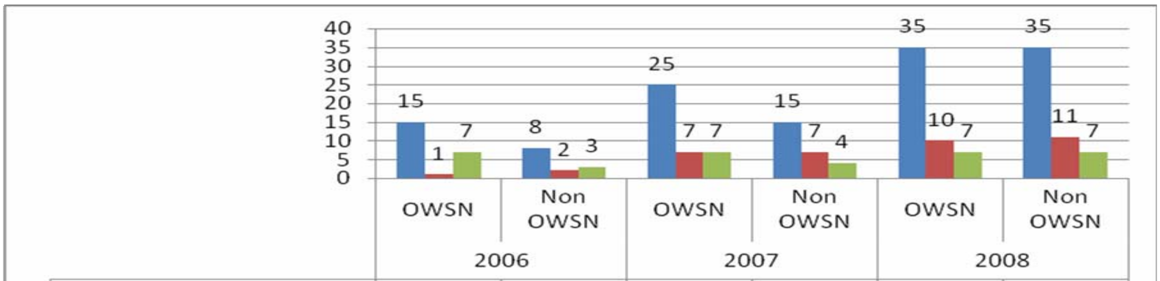
A series of annual weather science IBL tournaments was kicked off in 2006. The format of the tournament is a five-week event. Following the four-phase inquiry flow described in the previous section, and the four-phase inquiry worksheets listed in Table 1, the team members were asked to complete each inquiry phase and fill out issued worksheet every week. The last week was the oral presentation. Each team was composed of three or four students, and consulted by a teacher. Until now, there have been 171 teams which include 447 grad 4-9 students, and 220 teachers participated in the events. In 2006, there were twenty-six teams; 2007, fifty-four; 2008, ninety-one. In 2006, thirty teachers and sixty-seven students participated in the tournament. In 2007, seventy-one teachers and 144 students join the event. In 2008, the numbers of the teachers and students soared to 119 and 236. The statistics of the tournaments are listed in Table 2.

Table 2: Basic information of the series weather IBL tournaments.

	2006	2007	2008
Registered Teams	26	54	91
Number of Students	67	144	236
Number of Teachers	30	71	119
Invalid or Giving Up Teams	3	14	21

For statistic study, the registered teams were classified as OWSN (owing the weather sensor node) and non OWSN. In 2006, twenty-six teams registered to participate in the tournament. Among them, sixteen teams were OWSN and ten were non OWSN. In 2007, fifty-four teams attended the event. Among them, thirty-two teams were OWSN, and twenty-two were non OWSN. The registered teams in 2008 soared to ninety-one. Among them, forty-five were OWSN, and forty-six were non OWSN. The registered teams of non OWSN were over the OWSN teams in 2008, firstly. Furthermore, in 2006, among the sixteen OWSN teams, fifteen completed the inquiry activity, and seven teams won the awards. In the same year, ten teams were non OWSN. Among them, eight teams finished the five weeks inquiry activity, and only three teams won the awards. In 2007, thirty-two teams were OWSN. Among them, twenty-five finished the inquiry process, and seven teams won the awards. In the same year, twenty-two teams were non OWSN. Among them, fifteen teams completed the process, and only four teams won the awards. Before 2008, the OWSN teams' achievements, in general, were higher than non OWSN, but 2008 was a turning point. In 2008, forty-five teams were OWSN. Among them, thirty-five completed the process and seven won the awards. In the same year, forty-six teams were non OWSN. Among them, thirty-five teams completed the inquiry process, and seven teams won the awards; the same with the OWSN teams. The detailed numbers were listed in Figure 3.

TWIN platform was composed of sixty weather sensor nodes deployed in the sixty Taipei City elementary schools. It is expectable that the OWSN teachers and the students will pay much attention on TWIN platform. The issue of the TWIN platform usability will focus on the non OWSN teachers and students. According to the three-year tournaments data shown in Table 2 and Figure 3, in 2006, the participating rate, finished teams rate, and higher achievement teams, the OWSN students performed better than non OWSN students. The difference of the OWSN students and non OWSN students of 2007 was very close; although the OWSN students had very minor better results than the non OWSN students. In 2008, the two catalogs, OWSN students and non OWSN students, almost had the same performance. This indicated that the students whoever their school had the weather sensor node or not, they can perform well on TWIN platform.



	2006 OWSN	2006 Non OWSN	2007 OWSN	2007 Non OWSN	2008 OWSN	2008 Non OWSN
finished teams	15	8	25	15	35	35
incomplete teams	1	2	7	7	10	11
higher achievement teams	7	3	7	4	7	7

Figure 3. OWSN and non OWSN statistics.

Conclusion

In 2004, a city-wide wireless weather sensor network named TWIN (Taipei Weather Inquiry-Based Learning Network) composed of sixty weather sensor nodes was deployed in the sixty Taipei City elementary schools. TWIN, a WSN enhanced IBL platform, can record the whole Taipei City weather data each five minutes, and opens the data to the general public for IBL learning. TWIN demonstrated its abilities with offering real and instant weather data, allowing students to explore in a geographic free environment, providing effect and task oriented learning activity, facilitating collaborative learning, and preparing digital archive. A series of annual weather science IBL tournaments was kicked off in 2006 to encourage and engage the teachers and the students to use the TWIN resources. Until now, there have been 171 teams which include 220 teachers and 447 students participated in the tournaments. According to the study of the tournaments data, the usability of TWIN platform is satisfied. This study is a pilot study of applying novel wireless weather sensor technology to construct a city-wide weather wireless sensor network. For the teachers and the students, this is a new try, and new experience. By using the technology, it is expected that TWIN can provide much logistic support, and increase the students' inquiry interests and ability. The preliminary tournaments' quantitative data show the positive of using TWIN platform in IBL. Further study concerned with the practices of meaning making in the context of join activity, the students' achievement analysis, and micro case studies are needed to explore.

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Constructing the Face-to-Face Collaborative Game-based Interacted Environment for Portable Devices in English Vocabulary Acquisition

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Abstract: This study is aimed to develop a face-to-face collaborative English vocabulary acquisition game system on portable devices, called Wireless Crossword Fan-Tan Game (WiCFG). One class of 32 primary school students in Taiwan participated in this study. Students' learning outcome, motivation, and attitude were collected and analyzed. In their small group interaction, we analyzed and generalized three interaction modes: "Face-to-face interaction", "Device-media interaction" and "Human-device interaction". Significantly, a "face-to-face portable-device-mediated interaction module" was proposed. The preliminary research findings indicate that adopting the WiCFG could improve the learning outcome of lower-achievement learners. Using the WiCFG had positive enhancements of learning motivation and engagement. In the group observation, using the WiCFG improved learners more interdependent in group collaborative learning and was generally well-received by the English teacher and the students.

Introduction

English learning has been highly valued in Taiwan for a long time. The Ministry of Education in Taiwan declared that all primary school students must take English course from third grade. Besides the government policy, parents also focused improving the English ability of their children. Parents sent their children to learn English in informal ways based on their financial resources. An investigation on the current implementation of EFL (English as foreign language) learning in Taiwan primary schools was published by the National Teachers' Association R.O.C. and Citigroup (2004). It notes that the bimodal distribution of children's English proficiency has been a significant issue in primary schools. Traditional teacher-centric instructional approaches appear to be unable to benefit different students' learning. One of the thorniest problems teachers face is that lower-achievement students lack motivation to learn based on different English learning background and ability. Teachers are eager for a solution to this problem.

Therefore, in this paper, we develop the Wireless Crossword Fan-Tan Game (WiCFG) in order to motivate learners to learn English vocabulary. The purpose of the study is to ascertain the effect of using the WiCFG system with Tablet PCs as compared to using paper-and-pens in English vocabulary collaborative learning in terms of the learning performance, the motivation to learn English vocabulary, and the cultivation of interactions.

Face-to-face Group learning and interaction patterns

The interactions in groups decide the positive or negative collaborative results. Students enhance cognitive learning from memory through the interactions and negotiations in the group (Zurita & Nussbaum, 2004). Face-to-face CL activities may probably come up with disagreements or different points of view, so group members need to cultivate abilities for communication. In the Johnson and Johnson model of collaborative learning, positive interdependence is the key issue of the learning community (Johnson & Johnson, 1998). Individuals share common goals and individual outcomes are affected by the actions of others. Also, competition is considered an effective way to stimulate people progress (Julian & Perry, 1967; Whittemore, 1924; Yu, 2001). A competitive learning environment obviously stimulates different feelings in winners and losers. It is imperative to consider how to design such an environment so as to motivate learners (Chang et al., 2003). In a competitive game-learning environment, students are motivated to make efforts to achieve better performance (Chang et al., 2003)

Chen et al. (2003) recently confirmed that intra-group communication patterns exert a significant effect on group performance. To represent intra-group communication, Liao (2004) relied on Milson's (1973) communication patterns and took all possible interactive links among three members into consideration in order to illustrate the small-group interaction patterns shown in Figure 1. In that figure, links represent oral, emotional, or physical communications. Ideal and dominant leaders are defined as positive examples, since they reflect the features of cooperative learning more completely than other patterns. In Figure 1, the interaction links are defined as (Liao, 2004):

1. Ideal (three bidirectional links). Three group members interact via multiple communication routes.
2. Dominant leader, with individual bidirectional links connecting three group members.
3. Cliquish, with one bidirectional link between two group members, thus putting the third member in a position of isolation.
4. Unresponsive, with only one unidirectional link. A group member may try to communicate, but the other two fail to respond.
5. Unsocial, with zero links. Group members simply do not communicate.

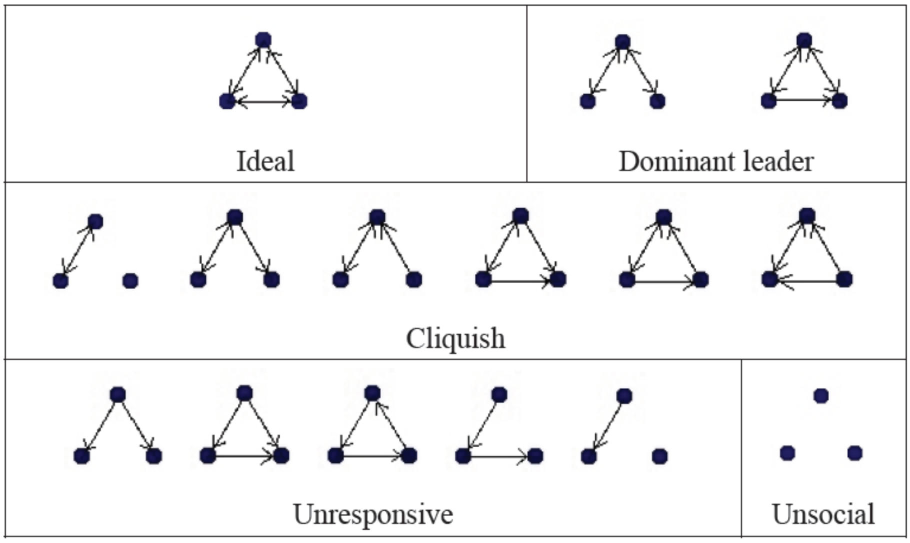

Figure 1. Small-group interaction patterns (Liao, 2004)

Mobile technologies and one-on-one digital classroom environment

Wireless and mobile technologies bring forth a unique opportunity to construct a seamlessly integrated learning environment (Joiner et al., 2003) and the notion of "one-to-one technology-enhanced learning" (1:1 TEL), a ratio of at least one computing device for each student, was coined (Cheng et al., 2006). A wireless technology enhanced classroom (WiTEC) which integrated with mobile devices, wireless communication, and network technologies can reduce the time for tedious work, engage students in learning activities, empower the teacher to monitor students' learning status, facilitate group collaborative learning, record teaching and learning processes as portfolios, and make portable wirelessly-networked technologies that has become ubiquitous and pervasive in the everyday lives of learners (Gay et al., 2001; Goldman & Kaufman, 2001; Liu et al., 2003)

CL is an important issue of 1:1 TEL, In the process of CL, it can be more convenient by using mobile devices. Mobility has dramatically increased portability and interactions between members and enables immediately exchange of different thoughts with appropriate amendments and responses. Studies (Inkpen, et al., 1995) show that compared with single-operator learning, the group collaboration learning would be a positive influence on performance of more effective cooperation for the achievement and joy.

WiCFG

In this study, we developed the Wireless Crossword Fan-Tan Game (WiCFG) gaming course environment. One class of 32 primary school students in Taiwan participates in this study. Each group contains three different level students (beginning, intermediate, and advanced). According to English used frequency, the English characters (from a-z) are dividedly distributed to group members equally, which group member can only see his/her own characters in "personal area" in WiCFG. Three group members share the same "group pubic area" to let members interact with each other synchronously. Group member can drag his/her own character from "personal area" to "group public area" to build the word collaboratively. Teachers can monitor the performance of each group, and collect all the results of groups in the data analysis area in teacher client.

Prior to the game, the teacher can assign the theme (ex: food, transportation, travel, etc.) to match the progress of the course. In the game beginning, group members need to build up the "word map" on public area collaboratively, they need to discuss which vocabulary should be chosen and negotiate with their own letters to accomplish word together. The word on the word map has to be negotiated and completed by the three group members with their own letters. The group which builds the most vocabulary matching the theme wins the game.

In order to understand whether deploying computer supported CL scenario by means of using Tablet PC with the WiCFG would benefit EFL vocabulary learning, we decided to examine the differences between using the WiCFG and paper-and-pens through the similar activity of English vocabulary (see Figure 2).

The research design of the study was conducted during the last semester of sixth graders who learn English as a foreign language in the NS elementary school of northern Taiwan. One class of 32 primary school students in Taiwan participated in this study. Classroom observers recorded the participants' interaction, motivations and involvement on the observation form, and four DV recorders focused on different assigned subgroups during the whole process. The participants were also asked to fill out a questionnaire which elicited information concerning their interface operation (in the experimental group only), attitudes, motivations and interaction. The interviewing data was collected a week after the survey was completed. Three successful and three less successful English learners were selected from both groups, based on these learners' performance during the activity. The length of each interview lasted from ten to twenty minutes. After each individual interview, we had a focus group interview for each subgroup. Participants were interviewed about their language background, interaction opinions during the learning process, and motivation especially focusing on the interaction. After all, the repeated measure ANOVA was used to detect significant difference among variables. Both qualitative and quantitative data were collected and analyzed.

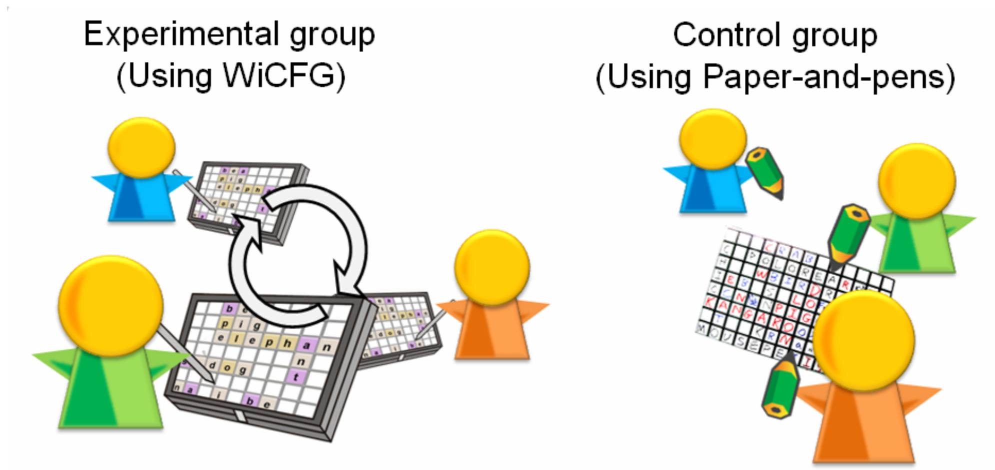

Figure 2. Experimental groups and control groups

Preliminary data findings and analysis

Learning performance of experiment group (E.G.) and control group (C.G.)

The data findings indicate that the result of the pretest (E.G., M = 10.20, C.G. M = 10.82) and the posttest (E.G. M = 12.46, C.G. M = 12.22). The results show that the students' scores in both groups improved after the activity. The analysis used the SPSS statistical software package, and the descriptive statistics were computed. According to the finding, in each instance, the mean posttest scores are higher than mean pretest scores. There are significant differences in the pretest/posttest of the experimental group ($p = .002 < .05$) and the control group ($p = .001 < 0.5$). The result indicates that there are no significant differences between the test scores for the two groups ($F=6.127$, $p=.11 > .05$), for high-achievement users ($t= 3.508$, $P = .468$). By contrast, there are significant differences between the low-achievement users.

Student's endurability, engagement, and expectation effects

This study analyzed students' attitude toward to game using the WiCFG and using paper-and-pens by the endurability, engagement, and expectations following Read's related research. The questionnaire provides the list of items that were used for classifying the data in this study, grouped into three categories. The Likert five point scale implemented in the questionnaire transformed participants' ideas to quantitative data (From 5 to 1 point mean strongly agree, agree, neutral, disagree, strongly disagree). The result of the questionnaire is shown as follow.

Endurability: Items 5, 8, and 10 score averaged 3.87 and 3.67 in E.G. and C.G, which shows the game using both WiCFG and paper-and-pens are endurable and have continuity in both groups.

Engagement: In this category, items 6, 7, and 9 had the average score in E.G. of 3.87, which means using WiCFG is beneficial to help students concentrate their attention to the game. However, in C.G., items 6 and 8 only scored 2.65 and 2.41, this shows that control group students are easily interrupted and distracted.

Expectations: Items 2 and 11 scored 3.59~4.24 in both groups, which show that both using WiCFG and paper-and-pens is expected by students.

The group interaction observation

In the most of the control groups, the observation shows that the paper and pens only used by one or two students. Students hardly use the resource and materials at the same time. Therefore, some students do not collaborate with their group members. Contrary to the control groups, the experimental groups have more interaction between group members. Based on the equal resources the members have, students need to negotiate with each other to accomplish the common goal set by each group. Furthermore, when focusing on low-achievement learner in each group, we find that the low-achievement learner in the experimental group interact with other two members more often than in control group. Low-achievement learners were ignored because they could not get the resource in their group.

Face-to-face portable-device-mediated interaction module

In the study of small group interaction, we add the media-mediated factor and generalized three interaction modes as follow:

Face-to-face interaction: In the small group CL activity, the activity supports face-to-face communication and social interaction between participants.

Device-media interaction: By giving each participant a wirelessly portable device, this allows participants to move freely in the group to interact with their group members through their portable computers.

*Human-device interaction***:** More than the Device-media interaction, participants also interact in the way that using other group members' device in the small group. The system design makes information available to the participants and fosters their social interactions and provided the conditions necessary for successful CL activities.

Significantly, a "face-to-face portable-device-mediated interaction module" is proposed. The portable computers can be moved freely in the classroom. In a face-to-face portable-device-mediated environment, it is possible to create both a technological and a social network between in the group. While the users communicated face-to-face in a social network, they supported their work with the technological network created by the portable computers. It is importance to transfer information from both the technological network and the social network in an effective way.

Conclusions and Discussion

In this paper, we reviewed literature related to collaborative learning and competition, a collaborative-competitive module was embedded into this constructive learning environment. Learning by doing and sharing was highly emphasized in this study. We developed a handheld-based English vocabulary acquisition game called the Wireless Crossword Fan-Tan Game (WiCFG), which facilitates English vocabulary building for accumulative learning. The preliminary research findings indicate that adopting the WiCFG could improve the learning outcome of learners, and it is particularly beneficial for lower-achievement learners. Moreover, using the WiCFG has positive enhancements of learning motivation and engagement. In addition, using the WiCFG improved interdependence between group members in collaborative learning. Overall, the teacher and students agree that the use of WiCFG and the advantages of one-to-one technology enhanced group collaborative learning. In the study of small group interaction, we added the media-mediated factor and generalized three interaction modes and face-to-face portable-device-mediated interaction module.

With the advancement of technology today, the characteristics of technology enabled us to use the portable devices to discuss and collaborate synchronously. Based on this rationale, we propose this study. We hope that the WiCFG will be applied in more learning contexts to facilitate students' learning motivation and increase the fun in English learning in the future. In addition, we expect that other researchers will apply the idea to design more teaching activities that might benefit learners in other different learning contexts.

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Designing Opportunistic User Interfaces to Support a Collaborative Museum Exhibit

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Abstract: This research explores how to support collaborative learning practices when science museum visitors employ their own personal mobile devices as Opportunistic User Interfaces (O-UIs) to manipulate a simulation-based museum exhibit. The sophisticated graphical capabilities of modern mobile devices have the potential to distract visitors, a phenomenon known as the heads-down effect. To study the impact of O-UI design on collaboration, a highly-dynamic "complex" O-UI was contrasted against more simplistic, "remote-control" O-UI design, in the context of a cancer-treatment simulation. As expected, when groups used the "complex" O-UI, there was less visitor-visitor interaction, but unexpectedly, their conversations were of higher quality. They also engaged in better task division and displayed better task performance. The increased attention "simple" O-UI users were able to devote to monitoring one another's actions seemed to encourage emergent competitive behaviors, which disproportionately affected the engagement of female visitors. "Complex" groups showed no gender-related differences in engagement.

Introduction

The vast majority of visitors to science museums attend in social groups, with one study of 348 of science center visitors revealing that 97% of visitors belonged to family, friend, or school tour groups (Korn, 1995). While at science museums, visitors tend to prefer to engage in shared learning experiences (Borun, 2002; Diamond, 1986; Falk, Scott, Dierking, Rennie, & Cohen Jones, 2004; Paris & Hapgood, 2002). By structuring exhibits to accommodate more than one visitor at a time, museums can further encourage groups of visitors to pause and engage in collaborative learning. The canonical model for a computer-based museum exhibit, however, is that of the kiosk: a desktop computer mounted in a stand-alone housing. With relatively small screens and either a touch-sensitive screen or an input device like a trackball or mouse to provide input, such kiosks really only support use by a single visitor at a time. Improvements in display technology have allowed for the use of very large screens that are easily viewed by multiple visitors at once, but the means by which multiple visitors can provide meaningful simultaneous input are still being experimented with in museums. One possibility is to look to mobile devices. More and more museum visitors are attending museums with mobile computing devices, like cellular phones, in their pockets, and many museums and researchers are interested in taking advantage of the increasingly sophisticated computational, communication, and display capabilities of such devices to enhance the museum-going experience (e.g., Bressler, 2005; Bruns, Brombach, Zeidler, & Bimber, 2007; Haneef & Ganz, 2002; O'Hara, et al., 2007).

The proposal made here is to allow visitors to commandeer their own personal mobile devices into service – using them as impromptu user interfaces to a computer-based exhibit with a large, shared display. Many mobile devices have short-range wireless communication capabilities (like wifi or Bluetooth) that can be used to transmit real-time input to the computer-based exhibit, and in turn real-time output can be transmitted from the computer-based exhibit back to the mobile device, where it can be displayed on the device's screen. These impromptu user interfaces, dubbed *Opportunistic User Interfaces*, or *O-UIs*, allow computer-based exhibits to scale up to support arbitrarily large groups of mobile-device-toting museum visitors. Moreover, each visitor (assuming he or she is in possession of a mobile device) has equal access to the input and output opportunities made available by the exhibit, thus increasing the group's symmetry of action (Dillenbourg, 1999). Although access to a shared activity can be considered a *necessary* precondition for collaborative learning to occur, it is not a *sufficient* condition to ensure that collaborative learning will take place. How to design these Opportunistic User Interfaces to encourage groups to take advantage of the provided symmetry of action and become engaged in practices that promote collaboration and collaborative learning is still very much an open question, one which this work begins to address.

The concern is that if visitors use O-UIs to join in a shared collaborative activity, the O-UIs could have the potential to draw so much of the visitors' visual attention that the exhibit's public display – and perhaps even the visitors' companions – become superfluous. Shared public displays can support collaborative learning (e.g., by providing grounding for conversation, and supporting the task monitoring needed for joint attention management), but only if visitors attend to them. So, even if O-UIs allow exhibits to scale up to accommodate groups of visitors, if the O-UIs also put a damper on visitor-visitor interactions, such an exhibit could only nominally be considered supportive of collaborative learning. Museums have had problems in the past with visitors getting so wrapped up in single-user mobile device applications (e.g., audio/visual guides) that they ignore their surrounding context – an effect known as the "heads-down phenomenon." There is evidence that increased visual and interactional "complexity" of a mobile device's user interface may exacerbate the heads-down phenomenon in museums (a notion that will not come as a surprise to parents whose children use mobile gaming devices). It is not known if this phenomenon would occur when *groups* make use of O-UIs, because multi-user activities have a fundamentally different character than single-user activities. The research presented here takes a first slice, contrasting a more "complex" O-UI implementation against a "simple" O-UI implementation, looking to see if the collaborative activities of visitors using O-UIs are negatively impacted by the visual and interactional complexity of the O-UI, while attempting to hold the remainder of the activity constant across implementations.

Background and Prior Work

The Heads-Down Phenomenon and O-UI "Complexity"

The Case Against O-UI "Complexity"

The primary application of handheld devices in museums is in the form of Audio/Visual (A/V) guides, which typically present the same auditory output as regular audio guides, augmented with the addition of visual output in the form of extra text content, images, or video clips [see Raptis, Tselios, Tselios, & Avouris (2005) for a review of the more well-researched A/V guides]. In museums, the presence of advanced multimedia has been shown to cause increases in learning measures like recall and visual recognition tasks (Bellotti, Berta, Gloria, & Margarone, 2002). So, as much as the technology allows, A/V guide designers usually seek to deliver high-quality video, images, and audio to visitors. Unfortunately, A/V guide designers may be victims of their own success – by fully engaging the attention of visitors, such devices serve to distract visitors from other elements of their museum experience.

Studies of an A/V guide dubbed the *Electronic Guidebook* at the Exploratorium, a hands-on science center in San Francisco, found that a large majority of visitors reported experiencing feelings of isolation, with some also reporting that because of their usage of the device, they were prevented from interacting with their human companions (Hsi, 2003). To quote one visitor: "I didn't really notice other people; I wasn't paying attention to anybody except for reading the screen" (Hsi, 2002). An observational study of A/V guide use at an aquarium confirmed these visitor perceptions: those visitors who engaged with AV guides were observed to be much more isolated than the average visitor (Bellotti, et al., 2002). This is a finding that paralleled the observations of an earlier study that noted that some visitors got "lost in hyperreality," and ceased paying attention to the surrounding context in favor of attending to the handheld device (Fleck, et al., 2002). The ability of handheld devices to usurp visitors' attention has been reported in other forums, to the degree where it's been given a name in museum practitioner circles: the "heads-down phenomenon" (Exploratorium, 2005; Walter, 1996; Wessel & Mayr, 2007).

A sign that the visual output of A/V devices may be primarily to blame for the heads-down phenomenon comes from (Bellotti, et al., 2002), who found that some visitors would willfully ignore the visual output of the devices, essentially using them as audio-only guides, so that they could pay more attention to the rest of the museum experience. In another A/V guide study, visitors were observed to get lost in the heads-down phenomenon predominantly when using a highly interactive "mini-game" (Thom-Santelli, Boehner, Gay, & Hembrooke, 2006). The evidence seems to imply that the use of mobile devices, and especially mobile devices with interactive visual output, may interfere with visitors' ability to attend to their companions, and, in turn, their ability to engage in collaborative learning with their companions while engaged in synchronous, co-located, highly-interactive activities.

Multi-User Activities and O-UI "Complexity"

The prior section discussed the heads-down phenomenon in the context of A/V guides, which are largely designed to be *single-user* activities. Much less information is available on the impact of mobile interface "complexity" on users when the activity has been designed explicitly to be *multi-user*. When mobile devices have been used to support synchronous (same time) co-located (same place) group activities in museums, they have been employed to allow visitors to choose between being supplied individualized or shared information about an exhibit (e.g., Aoki, et al., 2002; Grinter, et al., 2002; Kruppa, Lum, Niu, & Weinel, 2005; Woodruff, Szymanski, Aoki, & Hurst, 2001), or engage in cooperative treasure-hunt style activities (e.g., Klopfer, Perry, Squire, & Jan, 2005; Yatani, Sugimoto, & Kusunoki, 2004) or quiz activities (e.g., Thom-Santelli, et al., 2006; Yatani, et al., 2004). Apart from (Thom-Santelli, et al., 2006), none of these studies hinted that visually-rich, highly-interactive mobile displays would lead to the heads-down effect. In the author's own work studying the collaborative use of O-UIs in a *classroom* context, middle-school students exhibited no great difficulty in shifting their attention between the handheld device and the rest of the shared context (Lyons, Lee, Quintana, & Soloway, 2006a, 2006b), even though the O-UIs they were using featured many dynamic graphical elements.

Perhaps the social context is enough to ameliorate the heads-down phenomenon, regardless of the degree of O-UI complexity? The lack of clarity concerning whether or not the heads-down phenomenon would impair collaborative learning in the context of multi-user activities sparked the design of the experimental study reported in this paper.

Software Design

The experimental research reported on here was conducted as a smaller part of a larger Design-Based Research project (Barab, 2006; Brown, 1992) which had both a prospective (forward-looking) and a reflective (or evaluative) phase (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). The first phase of the project involved extensive *in situ* formative testing on the floor of a hands-on science museum, the Exploratorium in San Francisco. The purpose of the formative phase was to produce a computer-based testbed exhibit and Opportunistic User Interface designs that would have high external validity. This paper reports only on the second, reflective phase of the project, which was a controlled, experimental study that evaluated the use of a “simple” O-UI design against a “complex” O-UI design.

Activity Testbed Design

A “testbed” exhibit that would allow for multi-user interactions needed to be developed, but to be in keeping with the spirit of DBR, it was important that the testbed be a *plausible* museum exhibit (i.e., that it would have a high external validity). Hands-on science museums (unlike art or history or even natural history museums) do not usually present objects (like paintings, or artifacts, or fossils) to visitors. Rather, they present *phenomena* to visitors, by constructing hands-on exhibits that allow visitors to directly interact with phenomena like gravity, electricity, or human visual perception. Although computers cannot present phenomena directly, via *simulations* of real-world phenomena, computer-based exhibits can give visitors the same degree of interaction and experimentation provided by more traditional hands-on physical exhibits. For this reason, a simulation was chosen as the core of the testbed activity. The particular *type* of simulation (cellular automata) was chosen because it allows for emergence of patterns of similar outcomes, without ever showing the exact same ”result” twice: this is in keeping with the richness of outcomes possible with physical hands-on exhibits.

The first, and simplest, cellular automata simulation created was Conway’s *Game of Life*, wherein white and black dots in a grid swap colors based on a simple rule set (Gardner, 1970). The *Game of Life* is very abstract, so to create the testbed exhibit, its rules were expanded upon to present a more contextualized phenomenon: a simulation of cancer growth in human tissue. The simulation uses a grid of interconnected cells to represent the “patient” suffering from cancer. The cells are placed at the intersections of a grid, connected by blood vessel segments (see Figure 1). All cells are dependent on blood flow for survival, but they share blood vessels and thus implicitly compete for blood supply. As automata, each element of the simulation (each cancer cell, each healthy cell, and each blood vessel segment) maintains information about its current state in the form of variables, but shares a rule base with other automata of its type (i.e., all healthy cells obey the same set of rules, all blood vessel segments obey their own shared set of rules, etc.). There is no “controlling hand” to the simulation – the next state of the simulation is an outgrowth of each automaton performing its own state update.

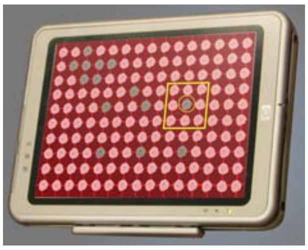

Figure 1. The cancer growth simulation (for the experiment, a large plasma screen was used in lieu of the tablet PC depicted here). Cells are arranged in a grid, connected via blood vessels. Clusters of the darker cancer cells act as “tumors.” The rectangle is the “incision” of a player, which can be moved from place to place.

Implemented in this manner, the simulation is relatively simple in its definition, but nonetheless exhibits several complex emergent phenomena that are hallmarks of cancer in real life: tumor growth and its associated angiogenesis, metastasis, and radiation-induced secondary cancers. Another advantage of implementing the simulation as a complex system simulation is that each “run” of the simulation is unique: although common patterns (like tumors) emerge, they do so in different locations each time. This adds to the replayability of the simulation, and to its educational value. When learning from simulations, “the main task of the learner [is] to infer, through experimentation, characteristics of the model underlying the simulation” (de Jong & van Joolingen, 1998). By ensuring that there are no “surface-level” patterns to master (for example, if the simulation were to follow a set, predictable pattern where the tumor always begins in the upper-left quadrant) learners are forced to understand the "deep-level" mechanisms. For example, the role blood supply plays in supporting the growth of tumors.

Visitors interact with the simulation by attempting to eliminate the cancer from the simulated patient. The simulation is tuned so that no single user can eliminate cancer alone – they must work together to accomplish the task. The intent was to support a version (albeit limited to divide-and-conquer strategies) of the jigsawed role-playing that was shown to be so successful at encouraging visitor-visitor interaction in (Klopfer, et al., 2005).

O-UI Design

HP iPaq h4100 handheld devices were used as a proxy for whatever devices a visitor may have with them when they attend the museum, as it was important to ensure that the devices be held constant for the experiment. Visitors were restricted a single role, Surgery, in an attempt to keep the activity as constant as possible across the two conditions, apart from how the O-UI design itself would alter the visitors' perception of the activity. Two O-UI designs were created and refined for the Surgery role: one which made extensive use of the touch-sensitive display screen (the "complex" O-UI), and one which operated more like a "remote control" (the "simple" O-UI) to serve as a baseline (without an interactive display to become engrossed in, "simple" O-UI users should not exhibit the heads-down phenomenon). Extensive formative testing on the floor of the Exploratorium helped refine these competing interfaces so that they would be easy-to-use in their own right (so that the experiment would not be a straw-man test) and so that they would have equivalent impact on the simulation (i.e., one O-UI design would not have a functional advantage as compared to the other; a process known as play-balancing in the field of computer game development).

After using an O-UI to log into the simulation, a small color-coded rectangle, labeled with the user's name, appears on the large plasma screen depicting the simulation overview (see Figures 1 and 3). Players are able to distinguish one another's representations on the shared screen using color-coding, a fairly standard approach in collaborative entertainment software (Bricker, Baker, Fujioka, & Tanimoto, 1998). The color-coded rectangle is an analogue to the "incision" that a surgeon can make into a patient, with the exception that this "incision" can be relocated by pressing the directional control pad buttons on the handheld device. When the surgery player makes "cuts" in the incision area, the cells and blood vessel segments underneath the "cuts" take damage.

Figure 2. On the left is the "simple" O-UI design. The image on-screen is a static placeholder. On the right is the "complex" O-UI design, which displays a detailed view of the cells within the "incision rectangle." The circle indicates where the user has drawn with the stylus to "cut" out the cancer cell in the middle of the display.

The "Simple" Surgery O-UI

The "simple" Surgery O-UI was originally designed to emulate a remote control, and thus did not make use of the display. Formative testing showed visitors were confused by the blank screen, and so a static instruction screen was substituted (see Figure 2). All input is provided via hardware buttons: the control pad "steers" the incision rectangle around the shared display, and the center button initiates an excision that damages cells within a certain radius. The amount and distribution of damage was tuned to be in keeping with the average damage patterns administered by "complex" O-UI users, so that the impact of "simple" and "complex" O-UIs on the simulation was equivalent.

The "Complex" Surgery O-UI

The "complex" Surgery O-UI was deliberately designed to occupy as much of the visitor's visual attention as possible, to maximize the severity of the "heads-down" phenomena should it occur in the context of a multi-user shared activity. Although "complex" users "steer" the incision rectangle in the same manner as "simple" users (with the control pad), surgery is performed by drawing circles on the touch-sensitive screen with a stylus, which (a) reflects an input style that is becoming increasingly common in mobile devices, and (b) maximizes the visual attention load, as hand-eye coordination is required from visitors in order to provide input.

Experimental Design

The experiment contrasted a "simple" O-UI condition against a "complex" O-UI condition, to determine the extent to which the heads-down phenomenon emerged in the latter condition, and if any differences in conversation patterns or task performance could be found that would correlate with heads-down behaviors. An "incomplete" repeated-measures design with rotation was used, meaning that each group experienced *both* of the experimental conditions, but the order of exposure was rotated to fully counterbalance any practice effects (Shaughnessy, Zechmeister, & Zechmeister, 2008).

Setting and Participants

The setting was a small, controlled room adjacent to the museum floor, created for use by the in-house Visitor Research and Evaluation group, and outfitted with state-of-the-art audio/visual recording equipment (see Figure 3). All user input actions were logged, as was each state update of the simulation. Groups of visitors were recruited through the museum's newsletter and from the floor of the museum, using a policy that *any* group with 3 or more members was approached to participate in an attempt to get a representative sample of the types of groups present in museums. Eleven groups were recruited: 4 were mixed-age families, and 7 were groups of friends, and the average group size was 3.3. The average age was 26 (the youngest was 10 and the oldest was 59, with a median age of 20). The gender ratio was roughly 45:55 female:male, with above 80% of the groups having mixed gender composition.

Figure 3. Photograph of the experimental setup: the 4' plasma screen used as a shared display and the handheld computers used by participants, as well as the stools used for seating. The hanging microphones used to capture audio are visible, and the structure mounted on the wall behind the plasma screen is the primary video camera.

Measures

Gaze as an Indicator of the "Heads-Down Phenomenon"

The name of the "heads-down phenomenon" suggests that users spend a majority of time gazing "down" at their mobile devices. The video was used to code the moment-by-moment gaze target for each visitor. The *Proportion* and *Duration* of gazes directed at the mobile devices were then calculated.

Conversation as an Indicator of Collaboration

The first coding pass differentiated *on-task* utterances (those relevant to the collaborative activity at hand) from *off-task* utterances to separate out participants who are actively engaged from those who are merely socially engaged, or chatty (Hertz-Lazarowitz, 1992). Although *on-task*/*off-task* binning indicates something about base levels of engagement in the shared task, two further passes were used to examine the on-task utterances. One was to determine how the utterances relate to the joint task execution (a *functional* perspective), and the other was to determine how the utterances relate to the context of the group's shared knowledge building (an *interactional* perspective). The *functional* pass attempted to single out on-task utterances for their potential to make a tactical or strategic impact on the group's behavior. Many utterances contain both tactical and strategic content, so a *Tactical/Strategic* versus *Nontactical/Nonstrategic* coding was used. The *Tactical/Strategic* category is very similar to the interpreting/applying category used in (Borun, Chambers, & Cleghorn, 1996), where family conversation utterances in museums were binned into three levels of learning: identifying, describing, and interpreting/applying.

Collaborative learning researchers often look for *interaction* patterns within conversational exchanges, to see if, for example, learners build upon each other's ideas (Palincsar & Herrenkohl, 1999). In a study that contrasted groups that succeeded collaboratively against those that failed, both *building upon* one another's comments and *echoing* one another's remarks were seen as precursors to effective collaborative learning (Barron, 2000). A related measure, *conversational elaboration*, is often used to study learning in museums (Paris & Hapgood, 2002). *Explanation-giving* is another conversational behavior often linked to effective collaborative learning (Bargh & Schul, 1980; Webb, 1984), and *explanation quality* has been found to correlate positively with small-group learning outcomes in classrooms (Webb, 1989). For the purposes of this study, *on-task* utterances were further classified as either *New Statements*, meaning that a conversational antecedent could not be found, *Responses*, meaning that the speaker is replying to or referencing an utterance made by a companion, and *Continuations*, meaning that the speaker is following up on an utterance he or she made previously. The proportion of *Responses* and *Continuations* made by group members can be taken together to provide a rough metric for collaborative conversation quality.

Shared Task Performance as an Indicator of Collaboration

Shared task performance can be measured by examining the actions users take within the activity. For example, if a participant damages more healthy cells than cancer cells, it can be safely said that the participant does not understand (or has a perverse desire to undermine) the shared task: to eliminate cancer cells from the simulated patient. An advantage to adopting a game-like activity structure for a learning activity is that there are often built-in measures of task performance: when users must attain some of the learning goals to be able to successfully complete the tasks, the task performance measures can serve as a sort of proxy for measuring learning (Lyons & Pasek, 2006).

Using the *individual* as the unit of analysis is a mainstay of traditional education, but to truly understand a collaborative learning context, the level of granularity needs to be that of the *group*, and measures need to be used that take into account group-level processes and structures (Greeno, 2006). Some educational researchers have begun using the concept of *participation equity* as a measure of the success or failure of the collaborative aspect of an activity (Kapur & Kinzer, 2007), a concept that has also been labeled “mutuality” (Barron, 2000). The rationale is that a group activity that encourages only *one* member of the group to pay attention, be engaged, or perform well cannot be considered a successful collaboration. For that reason, the participation equity of groups is taken into account: the assumption being that the higher the equity, the better the activity is at supporting collaboration.

A related concept is that of *task division*: in a collaborative activity, participants should be able to divide the task in a manner appropriate to that particular joint activity. Owing to the distribution and relatively fast spread of cancer cells in the simulated patient, the effective task division strategy for this experiment is a spatial divide-and-conquer strategy. This can be measured by the degree to which participants avoid overlapping their incision rectangles with their partners’ rectangles. The *ownership degree* is the proportion of time a participant’s incision does not overlap partners’ incisions. So if a participant *never* overlapped his or her incision rectangle with other players, he or she would have an *ownership degree* of 1. The *ownership degree* is also weighted by the number of overlapping partners. So if two players overlapped incisions with others for the same length of time, but one player overlapped with two or more partners a majority of the time, he or she would have a lower *ownership degree* than a player whose overlaps involved only a single other player.

Results

Gaze as an Indicator of the “Heads-Down Phenomenon”

The “complex” gaze patterns conform to prior anecdotal accounts of the heads-down phenomenon. There are no empirical results in the literature to indicate the boundaries beyond which gaze behaviors are categorized as heads-down, so the difference found here is reported to give the reader a sense of the span between the two extremes: the “baseline” established by the “simple” condition, and the intentional “worst-case” of the “complex” condition. *Proportionally*, more than half (66%) of “complex” user gazes were directed at the device (32% were devoted to the shared display) and the average *Duration* of gazes directed at devices was 13 s (compared to 3 s devoted to the shared display). When the same users were in the “simple” condition, the device captured only 14% of gazes (83% were devoted to the shared display) for an average of 3 s at a stretch (whereas shared display gazes lasted 21s).

Conversation as an Indicator of Collaboration

The analysis of raw conversational frequency indicates that, as the absence of the heads-down phenomenon might predict, “simple” O-UI participants have a significantly higher level of conversational frequency, about 6 utterances per minute as compared to about 4.5 per minute for “complex” users (see Table 1). The magnitude of the difference is not terribly large, and further analysis of the coded utterances reveals that, surprisingly, “complex” users engage in proportionally more *on-task* and *functional* talk, differences that are statistically significant. Nearly half of all utterances made by “complex” participants were on-task, compared to around one third for “simple” participants. There was effectively no difference in the proportion of *interactional* talk between the two conditions, however. What this indicates is that although participants converse less while using a more visually-distracting O-UI, they are no less likely to respond to one another – the continuity of conversation is not affected. The results show that a more “complex” O-UI, despite encouraging heads-down gaze behaviors and depressing overall conversation frequency, may actually *better* support collaborative learning, by discouraging *off-task* and non-*functional* talk. (Inter-coder reliability between the author and a second coder, after resolution of disagreements, was 94.4% for *On-task* coding, and subsequently 91.9% for *Functional* and 99.97% for *Interactional* coding on a previously uncoded transcript).

Table 1. Comparisons of overall conversational frequencies and proportions of coded utterances.

	"Simple" $n = 31$	**"Complex"** $n = 31$	**Significance** (paired t test), $n = 62$, $df = 30$
Conversation Frequency	$M = 6.07$ ($SD = 2.73$)	$M = 4.51$ ($SD = 2.62$)	$t(30) = 4.32$***
On Task Proportion	$M = 0.36$ ($SD = 0.18$)	$M = 0.49$ ($SD = 0.17$)	$t(30) = 4.04$***†
On Task: Functional	$M = 0.21$ ($SD = 0.14$)	$M = 0.30$ ($SD = 0.19$)	$t(30) = 2.79$**†
On task: Interactional	$M = 0.47$ ($SD = 0.20$)	$M = 0.49$ ($SD = 0.19$)	(none)

**p<.01, ***p<.001, † two-tailed test

Task Performance

Task Division

Because "simple" players attended more to the shared display, one might expect that they would be better at dividing the joint task, and thus have a higher *ownership degree*. Recall that if a participant never overlapped his or her incision rectangle with other players, he or she would have an *ownership degree* of 1: "simple" players had a middling *ownership degree* ($M = 0.55$, $SD = 0.13$), whereas "complex" players had significantly higher *ownership* ($M = 0.71$, $SD = 0.15$), *paired* $t(30) = 5.59$, $p < 0.00001$, two-tailed. From this evidence, it seems that "complex" players are better at engaging in task division. This echoes anecdotal observations made during the experiments: it seemed as though participants in the "simple" condition, rather than using the shared display to better coordinate their task division efforts, would instead rush to move their incision rectangles to the same places as their partners' rectangles and then target the same cancer cells. The players seemed to be uninterested in the coordinative aspects of the joint task in the "simple" condition. Oddly, the same players engaged in better task division in the "complex" condition, despite increased heads-down gaze behaviors, indicating that joint task monitoring is not automatically promotive of improved collaboration in the context of a shared computer-based museum exhibit.

Task Execution

Players also seemed less aware of, or less interested in, the underlying mechanisms of the simulation when in the "simple" condition. On a measure that compared damage done to cancer cells versus healthy cells, "complex" participants ($M = 0.74$, $SD = 0.17$) outperform "simple" participants ($M = 0.17$, $SD = 0.29$) four-to-one, *paired* $t(30) = 10.10$, $p < 3.7$ E-11, two-tailed. This may be due to the poor task division of the "simple" participants: trying to compete to eliminate the same few cancer cells resulted in much higher collateral damage to nearby healthy cells.

Participation Equity

Participation Inequity (PI), a concept borrowed from (Kapur & Kinzer, 2007), takes the within-group standard deviation (SD) to compute a measure of how *dissimilar* group members are from one another in their individual participation. So, if one group member dominates the activity by making the majority of moves, the within-group standard deviation of the number of moves made by each group member would be high. Examining the *PI*, we see that the within-group *move inequity* in the "simple" condition is larger on average ($M = 16.3$, $SD = 15.8$) than when the same groups were in the "complex" condition, ($M = 5.68$, $SD = 2.92$). It is also curious that the variance in *PI* across groups (i.e., group-to-group variance in inequity) was higher in the condition with higher visual monitoring (the "simple" condition). Utterances made by female players while using the "simple" O-UI seem to indicate that the variance may be related to gender. The following transcript is from when a group transitioned from the "complex" to the "simple" condition, and follows two older female speakers (East and South):

East: "Yeah, this is more like a teenage boy thing cause you gotta have that eye - uh"
South: "Yeah, pow pow pow" <Laughs>
East: "But you gotta move around really fast, you know what I mean? They're good at that."
South: "Yeah I know."
East: "I'm not as good at it."
East: [addressed to West] "Ok, you got em! You guys could do this game by yourself…

A *post-hoc* analysis seems to show that gender does indeed have a modifying effect on the move frequency measure. While females and males are very similar to one another in their move frequencies in the "Complex" condition (*M*=19.8, *SD* = 7.96, and *M* = 21.7, *SD* = 10.3, respectively, a difference of only 1.9 moves per minute), they show very different move frequencies in the "simple" condition (*M*=42.8, *SD* = 21.4, and *M* = 64.0, *SD* = 25.8, respectively, a difference of 23.2 moves per minute – ten times greater than the move frequency difference in the "complex" condition). Merely looking at these descriptive statistics is enough to show that there are stark gender-related differences for the "Simple" participants. What is not apparent from either dialogue or statistics is that after making her final remark ("…You guys could do this game by yourself…") East set down her handheld device, followed soon after by the other female participant, South, whereupon both stopped participating in the activity. This behavior – a participant putting down an O-UI – was never observed with a male participant, and was never observed with female participants in the "complex" condition, but was observed several times, for varying lengths of time, among females in the "simple" condition. Judging by the remarks quoted above, it seems that the increased monitoring of one's partners' actions in the "simple" condition lead to inevitable performance comparisons, and, in turn, to emergent competitive behaviors that may have intimidated females.

Conclusion and Future Work

Computer-Supported Collaborative Work researchers have long promoted the use of large, shared displays to encourage collaboration in shared settings (e.g., Stewart, Bederson, & Druin, 1999). In a work context, the ability to monitor the actions of one's companions was seen as an asset to collaboration, enabling co-workers to better coordinate. In the context of collaborative learning in classrooms, making the performance of individual partners public is often seen as a method to encourage all group members to participate in the joint learning activity, and discourage social loafing (e.g., Slavin, 1992). In this informal learning context, however, increased monitoring of one's partners does not seem to spur an improvement in collaborative practices.

The evidence here shows that while increased O-UI "complexity" may indeed cause users engage in gaze behavior consistent with the heads-down phenomenon, this decreased monitoring did not unduly impede collaborative practices. Participants spoke somewhat less while using the "complex" O-UI, but were just as responsive to one another as they were in the "simple" condition. Participants were more likely to make utterances that were *on-task* and focused on the *functional* aspects of the joint task when using the "complex" O-UI, which implies they were more focused on accomplishing the joint task. The task performance analyses confirm this: "complex" participants showed better *task execution*, showing that they better understood the underlying simulation mechanics, engaged in better *task division*, and showed better *participation equity*. The fact that the emergent competition seen with the use of remote-control-like O-UIs disproportionally affected the degree of female participation is of particular concern to museums, which must serve a wide variety of demographics. When O-UIs with interactive displays were used, however, gender-based differences in participation disappeared.

Thus, the "complex" O-UIs used here showed better support for collaborative learning activities despite being explicitly designed to encourage heads-down gaze behaviors. This suggests that the heads-down phenomenon is not as problematic for multi-user activities as it has been found to be for single-user activities in museums, giving designers permission to consider using mobile displays when designing O-UIs for collaborative activities. The experimental phase of research reported on here was followed by another "prospective" phase of DBR to more fully explore the design possibilities "complex" O-UIs make available. During this prospective phase, additional player roles were developed to complement the Surgery role, with the goal of supporting more of a true jigsaw-style collaboration between visitors. Trials conducted on the floor of the museum are still under analysis, but preliminary results suggest that providing orthogonal roles encourages deeper discussions of the underlying simulation rules.

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Research on knowledge practices with the Contextual Activity Sampling System

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Abstract: The Contextual Activity Sampling System (CASS) research methodology and the CASS-Query application have been developed for contextually tracking of activities with a mobile phone. The method relies on frequent sampling of participants' practices and affects during periods of intensive follow-up. Two research designs provide an account of the methodological development work and the possibilities offered by CASS. The first study followed five student-groups longitudinally to examine evolution of academic knowledge practices. The findings from the second year data-collection show that trialogical practices were considered challenging, but often generated optimal-flow experiences. The second study investigated interprofessional work during a clinical course. Based on this pilot study, it was concluded that the data collected about activities and experiences over time extend the understanding of students' practices beyond what can be acquired by post-course questionnaires and can help in development of the design of interprofessional education in medicine and healthcare.

Research on academic knowledge practices

The aims of the present research and development work are to provide a process-sensitive and contextual methodology for studying knowledge practices with a mobile tool. These compose the Contextual Activity Sampling System, CASS. The CASS enables one to investigate participants' on-going activities with frequent sampling during periods of data collection. The accumulating data can be used to examine individual, collaborative, and object-oriented aspects of activities.

The effort is a part of the Knowledge-Practices Laboratory project (KP-Lab, http://www.kp-lab.org), which is focused on promoting practices that capitalize on epistemic mediation (i.e., mediation through creating epistemic artefacts) and cross-fertilize knowledge practices between academic and professional communities. The central outcome of the KP-Lab project is an integrated KP-Lab System, which offers open source tools designed to facilitate expert-like practices of working with knowledge as well as for collecting (including the present CASS-Query application) and analyzing data on these practices.

Theoretical background

The three metaphors of learning, i.e., the knowledge-acquisition, participation, and knowledge-creation metaphor (Paavola, Lipponen, & Hakkarainen, 2004; Paavola & Hakkarainen, 2005), provide heuristic tools that assist in examining various aspects of learning. It is presumed that in learning there are always three aspects of human activity involved, i.e., subjective (individual learning and cognition), intersubjective (social communities and cultural interpretations), and objective (material culture and designed entities) represented by the three metaphors (cf. Davidson, 2001). While emphasizing the last approach, the trialogical approach to learning considers all three approaches as systemically interacting (see Paavola & Hakkarainen, this volume). Particularly for higher education, the trialogical approach aims at developing pedagogical models and tools for organizing learners' activities around shared 'objects', such as texts, models, conceptual artefacts, and also practices. Further, the research contributes to modeling and redesign of current educational practices.

Trialogical knowledge practices

By 'knowledge practices' we mean social and epistemic practices related to working with knowledge, i.e., personal, collaborative, and institutional routines. Schatzki has stated that practices are "embodied, materially mediated arrays of human activity centrally organized around shared practical understanding" (Schatzki, 2000, p. 2). These include carrying out learning tasks, solving problems, and creating epistemic artifacts, such as essays and research reports. Trialogical knowledge practices, further, are addressed as those collective practices, where a shared object is under development. These objects are created for some authentic purpose and foreseen as having value in a longer timeframe by external users, not only the producers. Such practices have also been referred as knowledge-creation. Institutionally, universities thrive on such practices in research, but as an educational practice, it is often conceived as something that takes place from graduate education onwards.

The present research contributes to the investigation of knowledge practices by sampling university students' ongoing activities and focusing on those aspects which relate to developing some objects collaboratively. Defining the central aspects needs to be continually refined both theoretically and methodologically. With longitudinal follow-ups and case-based investigations the present research addresses the interplay between cognitive, emotional, and contextual aspects in knowledge practices.

Optimal experiences

Prior research on academic emotions has examined various affects during studies (for review, see Pekrun, Goetz, Titz, & Perry, 2002); generally, they utilize stimulated recall or interview methods asking participants to report emotions in the prior situations to study academic emotions (Pekrun, 1992). Relying on experience-sampling methods, the research on flow (Csikszentmihalyi & Csikszentmihalyi, 1988; Delle Fave & Massimini, 2005) has highlighted the interdependencies of competence and challenge in defining the basic types of experiences. The four channel model (Csikszentmihalyi & Csikszentmihalyi, 1988) is often used to define different relationships between challenge and competence. Among these, *optimal* experiences are characterized by high challenge combined with adequate competency for the task or situation. It is often related to high concentration, enjoyment, engagement, and control of the situation, which are typical features of flow experience. By definition optimal experience is present when both challenge and competence are above one's own averages. For *relaxation* experience, feeling of competence is above one's average while challenge is below one's average. For *anxiety* experience, the opposite combination is prevalent; above average challenge is perceived while competence is below one's average. For *apathy* experience, both challenge and competence are below one's averages, and its occurrence has been associated with feelings of a lack of attention, concentration, and control. Furthermore, it has been suggested for example by Della Fave and Massimini (2005) that the positive psychological features of optimal experience have long-term effects on development; optimal experiences create a positive circle of enjoying the situation and looking for new suitable challenges, which recreate such feelings in the future.

Very often flow or optimal experience is taken as synonymous with a 'peak experience' or feeling of extreme happiness, or as Della Fave and Massimini express it, "optimal experience is frequently misunderstood as a state of fun, excitement, and ecstasy. Moreover, far from being an unusual or rare condition, optimal experience is part of the daily experience fluctuation, and it is prominently characterized by concentration and engagement rather than by happiness and amusement" (2005, p. 270).

Methodological development

The CASS methodology being developed relies on Experience-Sampling Method (ESM, Csikszentmihalyi & Larson, 1987; Csikszentmihalyi, 1996) and Ecological Momentary Assessment (EMA, Bolger, Davis, & Rafaeli, 2003; Reis & Gable, 2000; Stone & Shiffman, 2002), which provide methods of assessing participants' contextual activities, events, and personal experiences. Traditional survey methods are usually individually oriented and focus on the participants' beliefs and other discursive entities rather than their practices as they occur. A student may be asked, for instance, to assess how he or she prepares for examinations in general. The central weakness of this approach is that the participants are asked to provide retrospective global assessments (Reis & Gable, 2000) of their beliefs and conceptions of learning rather than recount learning activity unfolding in real time.

Contextual activity sampling, or more generally *event sampling*, has advantages over traditional survey research: an essential aspect of CASS is to provide a large number of measures (50-60 per participant) regarding learning activities across situations and contexts during periods of intensive follow-up. Data-gathering occurs in the context of respondents' everyday activities, which enhances ecological validity. Memory biases are decreased, as a participant is instructed to describe only the activities and affects from the last five minutes.

Contrary to survey methods, generalizations are made by researchers by aggregating observations or modeling changes across time by relying on time-series analysis or linear growth models. This data-collection method allows users to investigate within-person changes over time as well as between-person differences. The intended benefits include that the captured practices may be reflected on, modeled, and used to evaluate and revise learning and working activities.

Participants' knowledge practices may be sampled by different sampling strategies. The fixed-time sampling is suitable for time-series analysis, while event-contingent sampling may be used to track the occurrence of critical incidents. In the former, participants are prompted, for instance, every three hours to answer to preset queries. In the latter, participants are instructed to open the application and report key features every time the critical event or activity is occurring.

It is important to point out that although Contextual Activity Sampling and interviews are the main methods of data collection, we are also engaged in design-based research (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004; Design-Based Research Collective, 2003). This relates to the development of the CASS-Query tool and the data collection practices. Study 1, described below, will particularly explicate the iteration of the data-collection focuses and practices in the longitudinal study. Study 2 is a pilot study using a shorter version of the same queries in a clinical training ward context.

The CASS-Query tool

The CASS-Query application has been designed to provide researchers and the users with means to collect frequent and systematic data on ongoing activity (Muukkonen et al, 2007). The CASS-Query tool is a Java application that runs on 3G mobile phones with the Symbian operating system. CASS-Query delivers queries (surveys) to research participants' mobile phones in order to be answered, after which data are sent to a server database (see Figure1).

The main functionalities and features of the CASS-Query tool are

- Several question/response types are possible: open text (up to 1000 words), Likert scale, multiple choice, audio and video recording, picture question
- Several sampling strategies (e.g. fixed interval, event contingent, random)
- The content of the queries is fully determined by researchers
- Creating query forms without the need to learn a coding language (notation) with the CASS-Admin
- Ability to follow the accumulation of research data in real time
- Exporting research data in a format that they can be analyzed with a statistical analysis program (SPSS, Excel)

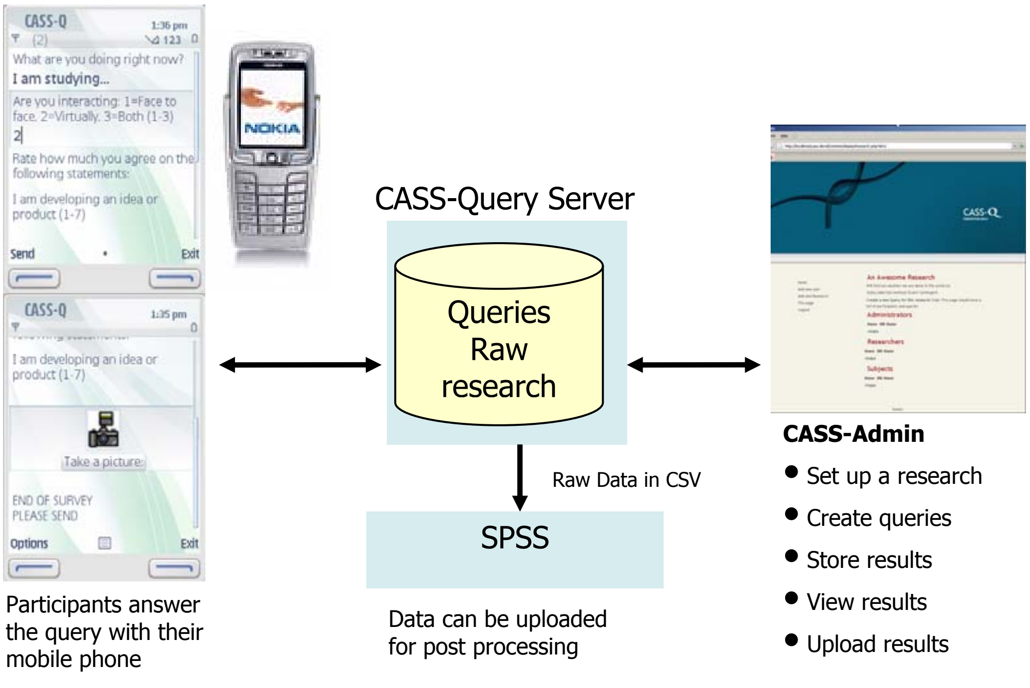

Figure 1. The CASS-Query research management and real-time data acquisition

The data-collection with the CASS-Query tool is administered with the web-based CASS-Admin, which is a wizard-like user-interface for setting-up research and creating queries. It provides accounts for data-collections, specifies the sampling strategies and the data-collection period, and allows setting-up personalized queries for participants. It enables to follow the accumulation of data and export data. Further, it enables reusing already created queries, and provides enhanced data security and user authentication.

In the present use, the mobile phones are preset to set off an alarm signal every three hours. This prompts the participant to open the application (e.g., at 8 and 11 AM and 2, 5 and 8 PM). The CASS-Query application then connects the server database and retrieves the intended questionnaire. After answering the query questions, participants save the data, which automatically returns the data to the database. Participants have considered the application very easy to use.

Study 1: A longitudinal investigation of object-oriented activities and agency

The first study describes a longitudinal investigation of higher education students' knowledge practices as part of their everyday activities. The study is planned to include intensive 3-4-year follow-ups with the same students. To repeat the data-collection, the students are asked yearly to take part in a two-week intensive data collection, questions prompted by mobile phone five times a day (e.g., Nokia E70).

First year follow-up design and findings

The baseline study was carried out in the spring of 2007, with 55 first year university students. At the University of Helsinki, there were two groups participating, educational psychology (n = 9) and teacher training (n = 6). At the University of Jyväskylä they were participants majoring in psychology (n = 20). In Espoo, student were engineering students from the Metropolia University of Applied Sciences, media engineering in the Finnish degree program (n = 13) and in the English degree program (n = 7). The mean age for students was 22.3 years (SD = 3.1), ranging between 19 and 37 years of age.

The first-year research has addressed questions on the sensitivity and the affordances of the methodology to examine knowledge practices and how the context of studying relates to affects and practices (e.g., how does context during studying relate to feelings of challenge, competence, and commitment?).

To explain the operationalizations of the measurement procedure, the main variables that are addressed in the findings are introduced here. We asked 'Do you feel stress? (1-7)' with a definition 'Stress means a situation in which a person feels tense, restless, nervous or anxious or is unable to sleep at night because his/her mind is troubled all the time. Do you feel this kind of stress these days?' This question was a one variable scale measuring stress, proposed by Elo and colleagues (2003). We asked about the self-reported object-of-activity in each query by asking the open question 'what are you doing right now?' to be answered by text. The query continued by asking 'how challenging is this for you? (1-7)' and 'how competent do you feel? (1-7)', related directly to the reported activity. The interaction of challenge and competence was used to defined emotional states (apathy, relaxation, anxiety and optimal) as presented above. We also asked about interaction: 'Are you interacting with someone else? (yes /no)' to find out whether the participant was collaborating with someone at the time of the query.

The study was designed as a 2-weeks follow-up accompanied with the participants' individual interviews concerning their personal projects and interests. Students answered five times a day to queries (see Figure 2). Circa 3400 responses were collected.

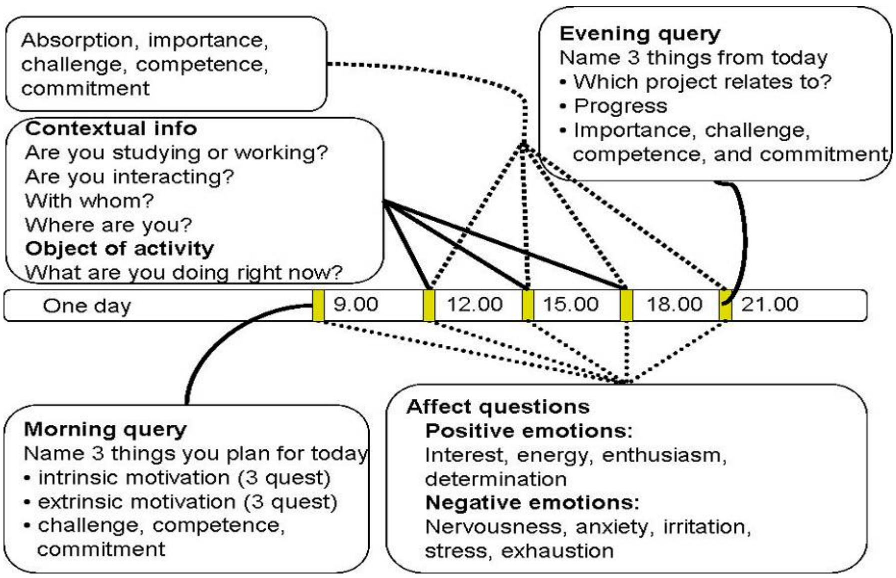

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Figure 2. Data-collection with Contextual Activity Sampling in Study 1

Within the three studied institutions, the students reported markedly different patterns of engagement in collaboration in the five degree programs, suggesting that the design of the curriculum may have a major impact on whether students end up working solo (more lectures and exams) or with peers (more projects and collaborative assignments). Further, working in small groups and library evoked positive feelings and flow, but lectures not (see Muukkonen, Hakkarainen, Inkinen, Lonka, & Salmela-Aro, 2008). However, our central interest had been to obtain data on the knowledge-creation practices, but our questions could not capture such practices adequately. A knowledge-creation type of object-oriented activity was rarely reported connected to studying: the few cases we identified of such type of activity were connected to engagement in leisure, e.g., recording a demo CD or preparing materials for some civic organization. A problem was apparent: how should we refine the queries in order to follow trialogical processes?

Second year follow-up design and findings

During the second year, data-collection was repeated with the same student-groups, which resulted in c. 2400 responses (40 participants). The research questions address methodological development (validity and reliability of the scale for trialogical knowledge practices), what emotional states (apathy, relaxation, anxiety and optimal) are experienced with trialogical practices during studies, and what kinds of objects of activity are associated with high challenge and trialogical practices during studying.

In addition to the first year's data-collection, a scale for 'trialogical practices' was developed. It posed questions like 'I am developing an idea or product', 'Results of this work can be utilized later', and 'I can contribute to others in this matter' on a 1-7 scale. In this paper we examine the results from studying context only. A sum score was created from these three variables (n = 761 and Cronbach's Alpha = 0.75) and it was normalized for each participants (average = 0 and standard deviation = 1). Further addition to first year was that the interview structure was modified to be able to focus more on longer-term activities.

Preliminary results indicate that self-reported objects-of-activity with high scores on trialogical practices were connected to activities like "I am planning a new web site", "I am rewriting and cultivating my essay", "Reflection on the phenomena studies", "Doing flash-animation", and "I'm starting my bachelor's work". Further, the higher scores students showed on the trialogical practice scale while they were studying, the more often they were experiencing optimal experiences, that is, participants experienced high challenge matched with high competence (Figure 3). When participants reported high values on the trialogical practice scale they, had often high challenges. Only 11 % of the responses rated as high (Z>1,3) in trialogical practices scale were associated with the four channel model states of relaxation and apathy, while 44 % were associated with anxiety and 45 % with optimal experience. It appears important in terms of the theory of psychological selection that optimal experience is reported most often with moderately high ratings of trialogical practices. This provides empirical evidence of the interdependence between knowledge-creation and optimal experience.

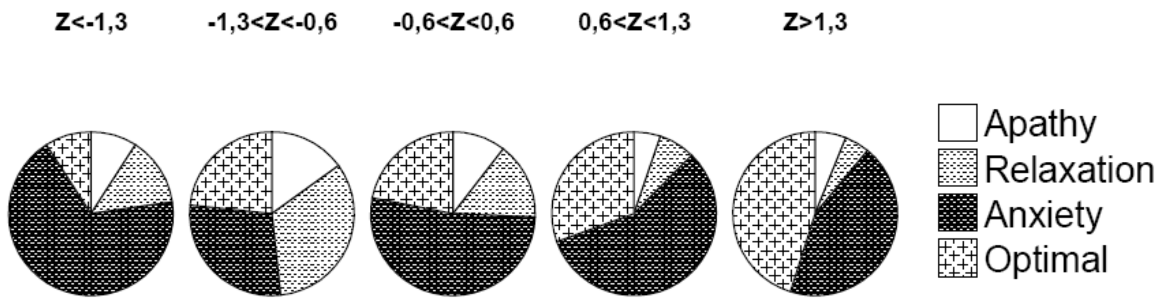

Figure 3. The four channel model experiences in different intensity classes of trialogical practice scale.

A qualitative examination of the self-reported objects-of-activity generated seven categories of activities: *writing*; *working on a collective object* or in a project (with a collective object); *study related activities* such as work in lab, doing homework or background research; *reading* book or notes and preparing for exam; *planning and preparing*; *following a lecture*; and *miscellaneous activities*. These activities were examined together with the different intensity classes of the trialogical practice scale and the four channel model of relationship between challenge and competence (see Table 1). Especially writing, but also planning and preparing as well as working on a collective object were often associated optimal experience and with developing an idea, perception that this work could be utilized later, and that a student could contribute to others with it. These results seem to confirm that trialogical practice scale measured phenomenon it was intended to measure as it captured writing, planning and preparing, and working on a collective object as trialogical activities. On the other hand, following a lecture was often associated with low scores on the trialogical practice scale and experience of low challenge and high competence (relaxation). Another interesting result was that study related activity (doing homework, or background research on one's own) was often associated with high challenge and low competence (anxiety).

In the interviews, a preliminary analysis suggests that the participants often linked their high motivation to competency, social interactions, and the opportunity to make a difference or collaboratively change the society (e.g., re-organization of education). In the interviews, some students in educational psychology pointed out that they have found collaborative inquiry learning activities interesting because they have been able to influence on what phenomenon has been defined as an object of joint inquiry and how it has been framed during these activities. Further, it was perceived more motivating because inquiry learning involves compact and manageable sub-tasks that can be addressed more easily than for instance larger (individual) assignments requiring the writing of essays. Some engineering students described in their interviews that personally meaningful activities might be originally evoked by course driven assignments (for instance activities related to coding); later on they wanted to improve their skills continuously. Some participants also highlighted the meaning of their participation in the activities of the Students' Union since that opens an opportunity to influence how the educational system will be organized in the future.

Table 1. Frequencies and deviations from expected frequencies (100 % means expected, >100 % more than expected, <100 % less than expected) of self-reported objects-of-activities in different intensity classes of trialogical practice scale and the four channel model of relationship between challenge and competence.

	Trialogical practices scale			**Four channel model of relationship between challenge and competence**				
	Z<-0,6	**-0,6<Z<0,6**	**Z>0,6**	**Apathy**	**Relax**	**Anxiety**	**Optimal**	
Frequency								
Miscellaneous activity	49	45	36	19	37	49	25	**130**
Following a lecture	13	34	36	6	13	43	21	**83**
Planning or preparing	1	6	26	4	9	10	10	**33**
Reading	10	63	185	16	9	137	96	**258**
Study related activity	4	25	55	6	4	60	14	**84**
Working on a collective object	4	34	110	8	11	77	52	**148**
Writing	1	2	22		1	13	11	**25**
	82	**209**	**470**	**59**	**84**	**389**	**229**	**761**
Deviations								
Miscellaneous activity	350 %	126 %	45 %	189 %	258%	74 %	64 %	
Following a lecture	145 %	149 %	70 %	93 %	142%	101 %	84 %	
Planning or preparing	28 %	66 %	128 %	156 %	247%	59 %	101 %	
Reading	36 %	89 %	116 %	80 %	32 %	104 %	124 %	
Study related activity	44 %	108 %	106 %	92 %	43 %	140 %	55 %	
Working on a collective object	25 %	84 %	120 %	70 %	67 %	102 %	117 %	
Writing	37 %	29 %	142 %		36 %	102 %	146 %	

The findings of the second year follow-up enforced the preconception that as a next step, the CASS data-collection needs to coincide with educational practices, where challenging knowledge-creating inquiry is targeted. We wish to learn more about the trialogical aspects of practices. Following the general curriculum design, such practices are more emphasized in the last-two years of studies, for instance during field-training or courses which involve working with external client organization and tasks. Such research design could involve following and recording face-to-face meetings focusing on the development and exploration of a shared object and epistemic actions, and simultaneously tracking critical moments in collaboration by means of CASS-data.

Study 2: Contextual sampling of experiences of an interprofessional clinical course

The aim of the second study is to pilot the CASS method and tools for collecting process and context sensitive data in the context of an interprofessional training ward at a hospital, by carrying out investigations of student experiences of interprofessional teamwork across time. The research questions have addressed the utility of the tool in the hospital training context and in interprofessional activities. Further, we wanted to examine how students with different professional backgrounds experience the course. This work is on-going; a pilot was carried out during the spring of 2008 and data collection continues during the fall of 2008 and spring of 2009.

The CASS-Query tool and 3G mobile devices were used to collect data five times a day about the participating students' experiences and everyday activities during the two weeks that the students work at the clinic. So far ten students have participated but 50-100 more participants will participate in the study. Also, post-course interviews have been carried out. The data that have been collected concerns psychological experiences which contribute to or interfere with 'optimal experiences'. The same affect scale was used as in Study 1; here we examine the results on stress, competence, enthusiasm, and collaboration variables.

Preliminary Findings from the Pilot Study

We were surprised by the level of participation and acceptance among the students since we were concerned that the frequent querying would be considered to be time-consuming and disturbing. But only two of the ten pilot subjects did not participate actively and the level of activity of those who did remained high during the entire course. Moreover, all those who did participate were positive and claimed that it was not time-consuming or disturbing. One even considered responding relaxing and an occasion for reflection. Only one of the subjects considered the number or questionnaires per day to be high. The two subjects who didn't participate did not feel it was meaningful to participate since they had been unable to get started from the beginning. None of the subjects felt that they had been watched or that the very intense data collection infringed on their integrity.

The collected data enabled us to see how the participants experienced the course over time and how different activities were associated with how they reported their feelings of stress, interest, challenge, competence, and experienced level of importance of the activity that they were engaged in. Figures 5 and 6 below show how a medical and a nursing student have reported their levels of competence and feelings of stress and the activity that they were engaged in. Some typical patterns can be discerned between activities and how these are associated with their experiences, e.g., the medical student experienced a high level of stress and a low level of competence when she met a new patient (unknown to her) at an orthopedic ward. Observations about such associations between students' experiences and activities can be useful in the design of the activities. For instance, efforts have been made to provide more opportunities for students to meet more new patients at the clinical training ward rather than at other wards which, as mentioned, was something that was a cause of stress to the inexperienced students.

While some such patterns can be identified, these associations are not expected to be simple and definite: there may be several reasons for how particular activities are experienced by students other than just the activities themselves. More informative may be to find general trends concerning experiences among different participants – the data enabled us to make detailed comparisons of how students with different backgrounds experienced the course. These diagrams illustrate that the experiences of stress differ clearly between this medical and nursing student. While both students appear initially to have experienced stress, the medical student has experienced a higher level of stress during most of the course whereas the nurse's stress level has dropped entirely towards the end of the course. Many interpretations are possible; one being that the medical student experienced more stress as a result of the responsibility of the patients that comes with her profession. And since each team consisted of only one medical student but several nursing students another interpretation is that having a higher number of co-workers belonging to the same profession provided support and therefore less stress. Regardless of which interpretation is most correct, identifying such trends can be very useful when refining the design of the course. Very little, or the absence of, stress may indicate that students' learning experiences are not optimal: perhaps they are not challenged enough or they feel overly competent for the tasks that they are engaged in. Such observations are constructive when further modifying and adapting the course to fit the students.

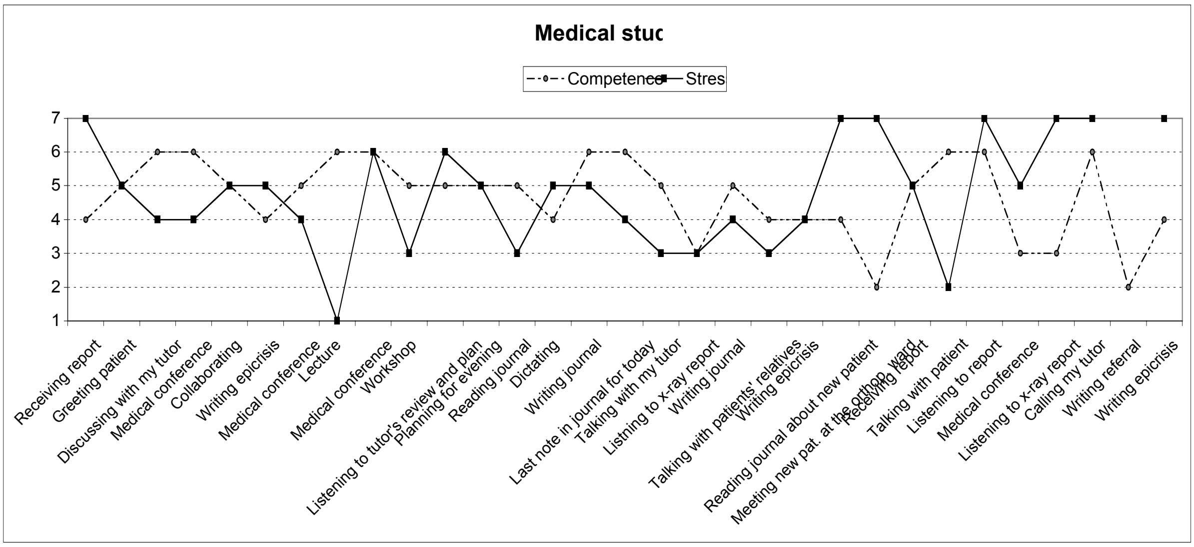

Figure 5. Experiences of a medical student related to activities during the course.

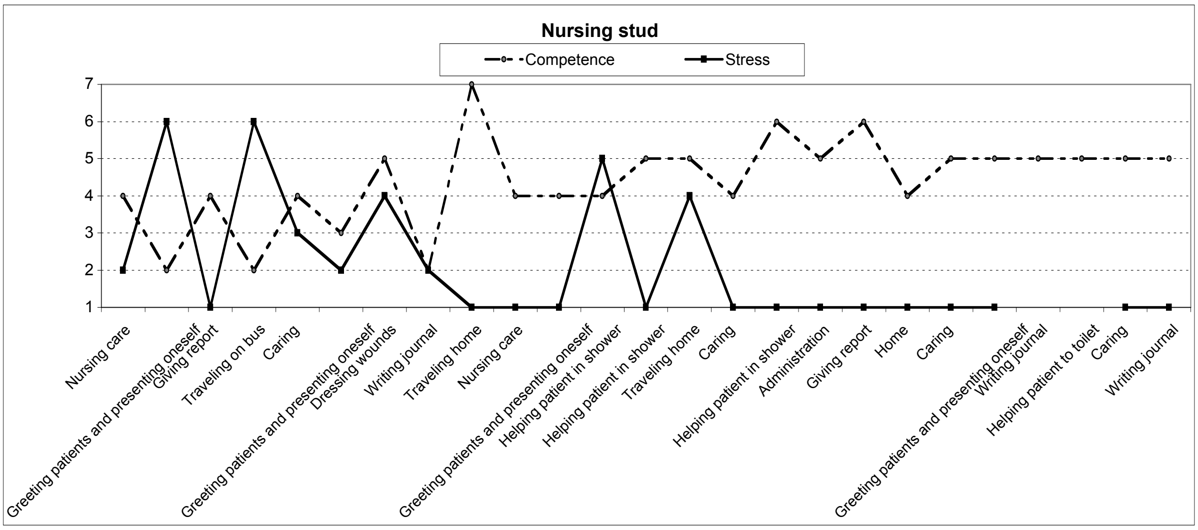

Figure 6. Experiences of a nursing student related to activities during the course

Another example of the findings shows that the levels of enthusiasm among the participants were higher when they were collaborating with other students than when they were working on their own (Fig. 7).

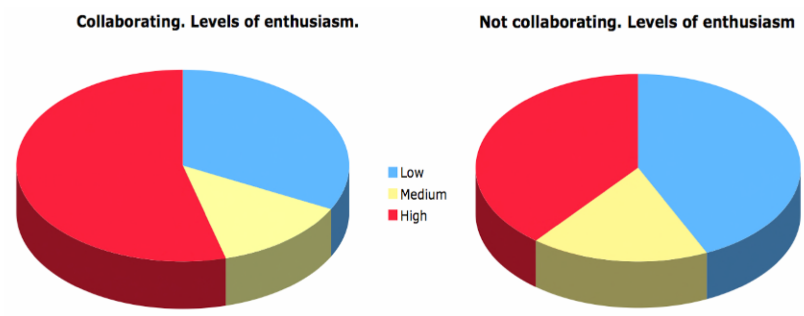

Figure 7. Students' levels of enthusiasm are higher when collaborating

As we have a particular interest in interprofessional teamwork, the students were asked to continuously respond to CASS-queries about whether they were collaborating with somebody and in that case with whom as well as how well they thought that the collaboration worked. The students responded when they were collaborating with fellow students of various backgrounds or their tutors and they mostly indicated that the collaboration worked well. Occasionally some students would indicate that the collaboration did not work well at all. We were naturally curious as to why and each CASS-query includes the possibility to write free text comments and we had hoped that students would use this possibility when problems occurred. This possibility was however not used. The fifth query sent in the evenings asked the students to summarize and generalize about the activities of the day and also addressed issues concerning possible benefits of collaborating with other professions. Occasionally they would indicate that they had no or very little help or use of students with other professional roles but they never elaborated on these issues and problems in the queries. A conclusion is that the CASS respondents do not spontaneously elaborate on their queries to any greater degree. The reason for this may be related to this kind of methodology: engaging in the intense query responding may limit the number of spontaneous comments from the participants. As a consequence using CASS requires being even more careful than usual when formulating and choosing which questions to ask – responses are obtained to the CASS questions but elaborations to these are not necessarily provided.

After the course each participant was interviewed about the course and using CASS. These interviews revealed a very positive attitude towards a number of issues relating to interprofessional work such as leadership, planning of work, quality of communication and evaluations as well as the utilization of available resources. None of these issues were considered to have posed any problems whatsoever by the students in the interviews, despite their earlier indications that collaboration was not optimal. Only one participant made a negative comment in the interviews about interprofessional teamwork concerning a medical student who he felt lacked interest and did not participate sufficiently in the teamwork. These positive results seem to indicate that the students were pleased with the interprofessional collaboration at the ward. But at the same time they seem overly positive and uncritical and we suspect that the post-interviews are not providing us with the detailed input that we need. There are many possible reasons for this; perhaps when the course is over the students do not have a need to be critical anymore – it will not change their working environment anyway. We believe that the CASS methodology can be especially helpful in addressing possible problems and challenges concerning interprofessional activities, provided that these are addressed explicitly and continuously in the queries. The issues need to be brought up as they take place rather than in retrospective questionnaires in the evenings or in post-course interviews.

To conclude, the detailed data about different student-categories' experiences over time extend the understanding of student practices beyond what can be acquired by traditional post-course questionnaires and may contribute to the development of the design of interprofessional education in medicine and healthcare. The pilot showed that the stress level seemed to initially be at a high level and then sink drastically to a level which was probably lower than ideal (too little stress may indicate that the students were not challenged enough). Although this result may only show the stress levels of these particular participants caused by something happening during their course rather being something caused by the course itself. E.g., the number of patients was not so high during the particular weeks may have led to the low stress levels. Nevertheless, this shows how data collected with the CASS-methodology can be valuable when evaluating and designing courses. Such observations would probably have been very difficult to make without the continuous context-sensitive data collection methodology.

The pilot has shown that the participants used the CASS mobiles to indicate when interprofessional collaboration was not optimal but they would not spontaneously provide elaborations on these incidents and after the courses these issues were not brought up in the interviews. This has led us to conclude that we should focus more on activating students in actively creating critical analyses of the interprofessional work that they were engaged in. Therefore in the further data collection means will be taken to specifically support analysis of the interprofessional work: rather than just respond to whether the collaboration works well the participants will be encouraged to continuously analyze the quality of the interprofessional work that they are involved in. Such activities can be viewed as a form of (trialogical) knowledge-creation and the CASS methodology is thereby not only used as data-collection tool but also as a tool supporting learners in their knowledge-creation activities.

Also, during the post-course interviews we plan to use graphs representing the participants' responses over time which thereby connect the interviews to the course's activities using the collected context-sensitive data as an input. Thereby it is possible to get the respondents' opinions of their earlier reactions many of which actually were more critical and which thereby could inform course development further.

Concluding remarks

This research contributes to the further development of the Contextual Activity Sampling methodology and associated CASS-Query tool which may have value for researchers or educators having interest in collecting detailed, contextualized data about students' or professionals' practices and experiences over time.

The first study described a longitudinal research design, which follows a number of students in three institutions over their four-year studies with yearly sampling of activities with CASS. Only a small subset of this research has been addressed in this paper. The development of the trialogical practices scale helped to operationalize some aspects Especially writing, but also planning and preparing as well as working on a collective object were often associated with optimal experiences and with developing ideas, perceptions that the work could be utilized later, and that the work could contribute to others. Optimal experience was reported most often with moderately high ratings of trialogical practices.

The second study presented how data collected with CASS and post interviews enabled to see how the participants of an interprofessional clinical course experienced the course over time. It examined how different activities were associated with feelings of stress, interest, challenge, competence, and experienced level of importance of the activity that they were engaged in. It suggested that data collected about activities and experiences over time extended the understanding of students' practices beyond what can be acquired by traditional post-course questionnaires and can contribute to the development of the design of interprofessional education in medicine and healthcare.

The two research designs presented have both employed a sampling strategy with five queries a day. It should be acknowledged that such a high frequency can be quite burdening to participants. In the design of data collection, the value of a high frequency of sampling should be carefully considered along with the possible drop-out of participants, particularly in repeated designs. Another solution could be to develop more context-sensitive or hybrid combinations of sampling strategies.

Our development efforts and the first studies using the CASS methodology have broadened our view of the scope of the applicability for the methodology. It is of particular value in settings where repeated data can be provided by participants in the study. This sets the methodology clearly apart from traditional survey methods. Secondly, it can be used to collect data in any setting, not predefined by the researcher. How well the research can capture different aspects of the participants' activities depends on how specific or general questions are used. We have already developed a 'super question', which can open or close alternative following questions.

The methodology has provided us unique and very rich data on the actual, evolving practices of the participants. We perceive the method to be most suitable to be used by adults. The scope of applications of the methodology can include studies, for example, on work ergonomics (by asking for instance mobile workers to evaluate their work load at different locations), follow-ups on counseling or medical advice or any number of research topics where the context and activities change and researchers are interested in these changes.

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From Handheld Collaborative Tool to Effective Classroom Module: Embedding CSCL in a Broader Design Framework

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Abstract: The TechPALS project expanded a general-purpose handheld CSCL tool (from Chile) to a 3-week classroom module for primary school mathematics (in the United States). To go from tool to module we articulated a framework for an effective CSCL practice– including curricular fit, training materials, pedagogical guidance, formative and summative assessments, and logistical support. In parallel, to meet requirements of the U.S. Department of Education, we conducted classroom experiments to investigate the achievement differences between students who were randomized to use either TechPALS or a non-CSCL product. In this paper, we examine the design changes from initial classroom pilot tests to eventual attainment of statistically significant results, emphasizing the integration of technology, activity designs, and broader educational practices that was required to achieve impacts in ordinary, low-income schools. Based on these results, we recommend a "curricular activity system" framework to support effective CSCL practices.

Introduction

The CSCL conference theme, *CSCL Practices*, suggests a maturation of the field from CSCL's traditional focus on design and analysis of collaborative learning with technology to also include more research on successful implementation of CSCL in broader instructional contexts. The Call for Proposals emphasizes the need for CSCL to "design and deliver appropriate technological tools that could be well integrated into educational practices and adopted by the pupils as well as designing associated learning activities, whilst exploring efficient ways to influence appropriately the corresponding contexts, on different scales." In tandem, we see an increasing emphasis in the field on what might be termed *CSCL Effectiveness*—comparisons of CSCL approaches to existing, non-CSCL approaches to the same subject matter. Random assignment experiments are a powerful methodology for such experiments, and an increasing number of experiments are being conducted in CSCL, particular in the area of validating CSCL "scripts" (e.g., Schoonenboom, 2008). We see a need for combining the practice and effectiveness perspectives to generate more research-based knowledge about *effective CSCL practices*.

In the TechPALS project, we aimed to investigate whether an existing CSCL tool from Chile, called "Eduinnova" might serve as the basis of an effective CSCL practice in American primary school classrooms. Eduinnova is a suite of software activities and database of content for wireless, handheld platforms. While these activities were not specifically mathematical, they could be adapted to mathematics tasks. To expand from Eduinnova to a classroom module, we integrated Eduinnova with a portion of the American mathematics curriculum, specified how it fit into American instructional practices, designed training materials and supporting classroom routines, incorporated formative assessment practices, and identified appropriate summative assessments. To evaluate whether the resulting classroom module, called TechPALS, was effective, we conducted randomized experiments in two schools in our pilot year and three more schools in the subsequent experimental year. As we will describe shortly, the pilot year yielded mixed results. This led to significant design iteration. Some of improvements were focused on the tool itself, but many were focused on the supporting framework. After applying this broader framework, we obtained statistical significant effects in our school experiments; students who used TechPALS learned more.

In this paper, we use these experimental results to provide a context for a discussion of the broader design framework that was needed to go from a tool to an effective classroom module. We describe three phases of design:

- From CSCL tool to pilot classroom module
- From pilot classroom module to implemented classroom module
- Beyond the module implemented in our experiments: What is needed next?

We begin by briefly describing the Eduinnova tool and reviewing relevant theory and research.

Handheld CSCL

Within the fields of CSCL and mobile learning, investigators have developed a number of approaches to using handheld devices to support collaboration among students (Chan et al., 2006). Many of these approaches emphasize applications in museums (Yatani, Sugimoto, & Kusunoki, 2004) or in the outdoors (Tan, Liu, &

Chang, 2007), where handhelds' mobility is naturally required because of the setting. The low-cost and ease of integrating devices into everyday classroom routines makes handhelds also attractive for in-school uses (Roschelle & Pea, 2002). Focusing on these in-school uses, Nussbaum and colleagues designed software that runs on low-cost mobile devices in support of collaborative activities among students working in small groups, targeting typical school subject matter (Cortez, Nussbaum, Rodriguez, Lopez, & Rosas, 2005; Zurita & Nussbaum, 2004). This software and the related activities are called "Eduinnova." After successful initial trials in Chile, Nussbaum sought collaborators in other countries who could leverage Eduinnova in further research and development. SRI decided to test the approach for the teaching of fractions for fourth grade (age 9) students in American primary schools.

The theoretical approach underlying Eduinnova builds on stable bodies of research-based knowledge in cooperative learning and formative assessment. Two well-known key principles for designing these effective cooperative learning patterns and incentives are:

1. *Positive interdependence*: The task should be designed so that individual contributions are needed for group success; "students need to know that they sink or swim together." (Johnson, Johnson, & Holubec, 1998, p. 4:7).

2. *Individual accountability*: The task should be designed so that each individual has their own work to do and cannot expect to succeed be freeloading on the efforts of their partners (Slavin 1996).

Meta-analytic studies of cooperative learning have found a positive effect for cooperative learning interventions that incorporate these factors. In a review of 104 studies, Johnson and Johnson (1987) found an effect size of +0.78 favoring cooperative learning over individual learning. In a review of 52 studies, Slavin (Slavin, 1996) found a +0.32 effect size favoring reward structures in cooperative learning that include the features of positive interdependence and individual accountability.

Formative assessment incorporates the notions of rapid, useful feedback to students and teachers. In a meta-analysis of 58 studies, Bangert-Drowns and colleagues (Bangert-Drowns, Kulik, Kulik, & Morgan, 1991) found a modest overall positive effect (+0.26) for feedback on student achievement. A second meta-analysis by Kluger and deNisi (1996) found higher effects when students were given feedback on the correctness of their solution methods and on their improvement from earlier trials and when they were using computers. Effect sizes for feedback for these interventions ranged from +0.41 to +0.55. Finally, other individual investigators have found that some of the most effective forms of feedback (1) guide improvement on a student product as it is being made or (2) guide teachers to adjust students' instruction (Butler & Winne, 1995). In fact, researchers (Fuchs & Fuchs, 1986) found large positive effects for achievement when teachers were required to alter their educational program for students if particular patterns in data were found (ES = +0.91).

The Eduinnova software aims to support both cooperative learning and formative assessment principles. By managing the work of assigning roles in collaborative tasks to students, software can make it easier to implement CSCL in the classroom. Further, by providing rapid feedback to students and teachers in a relevant and comprehensible format, software can make it easier to implement formative assessment.

Four activities drew our initial attention as fitting our target domain of 4th grade fractions: Consensus, Exchange, Ordering and Aiming Between. We describe each briefly below, with specific attention to how they support cooperative learning and formative principles. We also discuss the feedback provided to the teacher in the Eduinnova framework.

Consensus

In the Consensus activity, each student in the group of three receives the same multiple choice question at the same time (Figure 1). Each student enters an answer independently (individual accountability); however, the system requires that students agree on an answer (positive interdependence) and provides feedback only at the group level. If students do not choose the same answer, the software tells them they must agree, which generates much discussion. Once students agree, the software tells them whether they were all right or all wrong (formative assessment). If wrong, the software makes the previously incorrect choice unavailable so that students individually select a different answer. The group may not go to the next problem until they have answered correctly. After several failed attempts (usually three), the software will only allow them to choose the right answer.

Exchange

In the Exchange activity, each student receives two representations of a fraction, such as a numeral representation and a pie representation (Figure 2). Each student's goal is to match the representations on his or her screen. A match is achieved if the representations depict equivalent fractions. To achieve a match, students exchange representations within their group (positive interdependence). When all three students think they have a match, they check their answer. Similar to Consensus, the software tells the students only that all the matches are correct or that at least one student does not have a match. It is up to the students to determine who has the mismatched representations. Because of the need to both exchange representations and find mismatches, students have to interact with each other cooperatively. Further, because one student may have the numeral 1/2 and another student a pie showing 2 of 4 shaded sections, the students are encouraged to explain to each other why particular representations are or are not equivalent. After several failed attempts (usually three), the software indicates the correct answer.

Figure 1: Three handhelds showing the main screen from the Consensus activity

Figure 2: Three handhelds showing the main screen for the Exchange activity

Ordering

In the Ordering activity, each student in the group of three receives a unique fraction between 0 and 1. As a group, the students must input the fractions in a sequence of ascending order. Each student must submit her fraction at the right point in the sequence. Once all group members have submitted their fractions, the system will evaluate the submitted sequence. If the group has submitted an incorrect sequence, the system will give them another try.

Aiming Between

In the Aiming Between activity, consists of two parts: generating a unique fraction and evaluating fractions on a number line. Each student in the group of three receives the same representation of a number line with a target interval highlighted as shown in Figure 3. The number line always starts at 0 and ends at 1. The target interval and tick mark divisions vary from item to item. Each student tries to construct a fraction that would fall in the interval of the number line that is targeted. For example, if the target extended from 24/100ths to 51/100ths, a correct response would be any fraction greater than or equal to 24/100 and less than or equal to 51/100. Each student enters her answer independently (individual accountability). After all group members answer, the system checks to make sure that each group member has submitted a unique fraction (equivalent fractions are accepted). If a group member has submitted an answer that had already been given, the system instructs her to submit a unique answer. Once the group has submitted unique answers, the system allows the group to proceed to an answer evaluation screen. Each group member evaluates each of the three answers as either correct or incorrect. If the group members do not agree on the correctness of a response, the system instructs the group to come to a consensus. Once all group members evaluate the three answers in the same way, the system evaluates whether the consensus evaluation is correct. If the group has evaluated correctly, but did not submit at least one correct answer, the group must start over. If the group has evaluated the answer choices incorrectly, they must evaluate the answers again. After three incorrect evaluations, the system displays color-coded arrows on the item's number line representation showing the location of the students' answer choices along with a list of the submitted answers. Again, feedback occurs only at the group level, and students must agree (positive interdependence). Once students agree, the software tells them whether they were all right or all wrong (formative assessment).

Figure 3: Handheld showing the fractions construction screen for the Aiming Between activity

Feedback to the Teacher

Across all activities, the teacher receives feedback on how the students were doing. The feedback was organized as a simple grid of groups (rows) by problems (columns) as displayed in Figure 4. A cell in the grid is colored green if the group gets that problem right on the first try, yellow if the group gets the problem right on a later try, and red if the group exceeds the number of allowed trials. By scanning the grid, a teacher can identify groups that are having trouble (many red cells in the row) and provide assistance. Alternatively, the teacher can focus on a particular problem (many red cells in a column) that requires additional explicit teaching. Thus the teacher can enact formative assessment by adapting their instruction to fit emerging student needs.

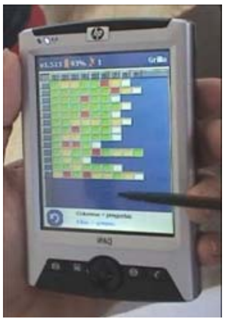

Figure 4: Handheld showing the teacher feedback screen

Year 1: Design and Pilot

The TechPALS design process involved both development work and pilot testing, both of which took place in the first year of the project, the 2006-2007 school year. The development work involved adapting Eduinnova activity structures to 4th grade fractions content and designing training materials for students and teachers. The pilot testing work involved identifying or designing measurement instruments and conducting preliminary field tests in classrooms. We describe our process for both the development and pilot testing work below.

Initial Design of Classroom Modules

Our first big decision in fitting the CSCL activity into a larger instructional framework was to target collaborative learning to a specific phase of instruction. In broad terms, we saw instruction as composed of three phases of instruction: 1) teacher-led presentations and discussion, 2) student-centered practice, and 3) homework. We decided that TechPALS would deploy collaborative learning as an alternative to individual student practice.

To support development of suitable activities, we organized the content of 4th grade fractions into two categories, concepts and procedures, each with three subtopics. We decided to focus on three important concepts of rational number: number, part-whole, and measurement. We organized our thinking about rational number procedures into three categories: operations (adding and subtracting), equivalence, and ordering (including comparison). The design team then proposed four activities, each based on prior Eduinnova activities, which would collectively cover the concepts and procedures, as shown in Table 1. (Please note that we understood that the concepts and procedures interconnect and did not propose teaching them in isolation; rather multiple activities allowed us to vary the emphasis and ensure coverage.)

The Consensus activity, because it is based on multiple-choice questions, can address all concepts and procedures. However, we did not want to use only this activity because of the potential for students to lose motivation. We conjectured that the Exchange activity would be particularly appropriate for the concepts and procedures relating to equivalent fractions. This activity format focuses students on matching different representations of the same quantity. For example, the students may be challenged to match the fraction 1/4 to a pie divided into 8 equal slices, two of which are shaded. In each group of three students, students would have three equivalent fractions to match, expressed in either the same or two different representations. The Aiming Between activity was intended to focus on the concept of a fraction as a number on a number line and to require students to construct fractions (rather than choosing among numbers already expressed as fractions). Finally, the Ordering activity introduced a new form of engagement because it required students to press a button at the right time to correspond to the place of their fraction in an ordering from smallest to largest. After the activities were determined, we developed databases of content for the individual items in each activity based upon a detailed analysis of the content in the curriculum and research suggesting the kinds of problems that students would find to be difficult.

Table 1: Four Activity Types to Cover Mathematical Concepts and Procedures

	Concept			Procedure		
Activity Type	Number	Part-Whole	Measurement	Operations	Equivalence	Ordering
Consensus	✓	✓	✓	✓	✓	✓
Exchange to Match		✓	✓		✓	
Aiming Between	✓		✓			
Ordering	✓					✓

Based on prior research (e.g. Webb, 1991), we realized it would be necessary to provide training to students and teachers about the desired cooperative learning behaviors. To encourage TechPALS students to engage in appropriate collaborative behaviors, we developed "The Cooperagent" a short multimedia presentation and storybook about an agent who models collaborative learning behaviors and training. Teachers received parallel training on their role in supporting cooperative learning. Consistent with the recommendations of Webb (1991), students were guided to explain their answers and procedures and to ask for explanations, not just "the answer."

Pilot Testing

We tested our initial materials in three schools, each with different standings according to the California Academic Performance Index (API, used to rank California schools' academic achievement from low to high).

1. A bilingual school in a major urban center, middle API.
2. A school in an affluent suburban location, high API.
3. A school in a relatively poor suburban location, low API.

In each case, the school used TechPALS for 2-3 weeks, however only schools 2 and 3 were teaching fractions while TechPALS was being implemented. We collected observational and test score data during the pilots. Five key findings emerged:

1. The approach did not seem to work well in the school with low API due to severe behavioral problems. It also did not work well in the school with high API; the students had already mastered the material. It did work well in the bilingual school with middle API.
2. The assessment we used, the Iowa Test of Basic Skills (ITBS), did not have enough fractions items on it to measure the learning we were seeing through observations. Further, the items that did exist on this test were mostly procedural; the test did not pick up conceptual gains.
3. The ordering activity did not work well as a cooperative learning activity. In many cases, we observed one student directing other students to press buttons in sequence. The other two students were therefore passive. We were discouraged by the level of training it might take for students to do this activity more collaboratively.
4. Technical problems reduced time on task.

5. Although collaborative behaviors were observed, we felt they could be more strongly encouraged.

Discussion

Our first step in going from the Eduinnova tool and activities to a classroom module was to determine a place for CSCL in instruction; mainly as a replacement for time typically allocated to individual practice. Although this may seem somewhat trivial, time is a major problem in American classrooms—if teachers are required to find additional time for technology use, teachers tend to use technology less and less. Also, because American classrooms are highly accountable to curriculum standards, it was important to direct technology use to a critically important and difficult topic, such as rational number. In addition to curricular fit, we produced training materials to introduce desirable collaborative behaviors to students and teachers. While our initial research focused more on the technology and student use of the technology, we quickly came to realize that the context of practice needed additional attention if we hoped to realize and measure the potential benefits of a CSCL approach.

Year 2: Design Refinement and Randomized Experiment

In Year 2, we refined the design considerably. The design refinements offer a look at the broader issues that must be tackled to integrate CSCL into ordinary classroom instruction. In addition, we conducted an experiment across three schools, which demonstrated statistically significant results. Observations, however, suggested another phase of design would still be needed.

Design

We discuss our refinements in order from the broadly contextual to the narrowly technical.

First, we decided that TechPALS could not be expected to produce results in schools with severe behavioral difficulties (collaboration was an unlikely when students were frequently misbehaving). Further, although we could have made TechPALS appropriate for advanced students with more time to produce adaptive databases of content, in the short run we decided the content was not appropriate for affluent suburban students who were more than one year ahead of their lower-income peers. Hence, we determined to target TechPALS towards schools that were in the middle of the API distribution, not at the tails.

Second, in order to measure both procedural and conceptual gains, we switched from the commercial ITBS test to an established research-based test for primary school fractions content. Because the test was targeted to students who were one year older, we supplemented the test with some additional items.

Third, we further specified the fit of the TechPALS module to overall instruction – we analyzed the textbooks teachers would be using and specified an interleaving of teacher-centered presentations (without TechPALS) to student-centered practice (with TechPALS), so that teachers would present the appropriate concepts and skills shortly before students would practice them in TechPALS. Further, whereas in the pilot a specially-trained "teacher aide" introduced TechPALS, we provided more support to teachers so that they could be in charge of the activity. We did this because we observed that students were less inclined to take the activities seriously when their ordinary classroom teacher was less involved.

Fourth, we sharpened the training materials (Cooperagents). To help students concentrate on the conceptual and procedural aspects of the math, we simplified and focused the Cooperagents training on the core cooperative learning skills of asking and answering two kinds questions, "how?" and "why?" With this focus, we were able to provide more examples to students of what they should do. Further, we added a group challenge, which emphasized the need for students to help each other. In the group challenge, each student in the group answered a test question, working quietly and individually. Each student, however, received a score that was the sum of the number of correct answers in their group and these were publicly posted. Students quickly surmised that to get a high score, they would have to support learning for all members in their group during the practice sessions.

Finally, we dropped the Ordering activity (because it was susceptible to non-collaborative behaviors) and focused on only the remaining three activity types. In addition, we refined the technical design to reduce the network and login problems that had reduced time-on-task.

Experiment

We describe the experiment in brief here; a longer manuscript has been submitted to a journal, where we will have the longer space required to fully describe our experimental design, procedures, and results.

Our hypothesis was: "Students assigned to the TechPALS intervention will outperform students assigned to work individually in a computer lab." We tested this hypothesis by randomly assigning individual students to solve fractions problems during practice sessions using either TechPALS or a commercial software program. We selected iSucceed Math (formerly Larson Intermediate Math) for the counterfactual condition. This widely used commercial software provides students a bank of practice items organized by topic.

We recruited two classrooms of fourth-grade students in each of three elementary schools that were in middle of the distribution of schools on California's Academic Performance Index. The school populations were approximately half Hispanic, 59% from families in poverty, and 45% English language learners. In the first half of each mathematics period, classroom teachers provided their usual instruction to students. We arranged for half the students from one teacher to exchange classrooms with half the students from a neighboring mathematics teacher for the portion of the class period devoted to student-centered practice. In one of the two newly mixed classrooms, students used TechPALS for practice and in the other they used iSucceed Math. This design counterbalanced the effects of the different teachers across the two conditions. Further, the design ensured that students in both conditions spent the same amount of time practicing fractions with technology. Because we used random assignment to form the mixed classrooms, we have no reason to suspect any systematic bias due to the classroom of origin. Students were given a pretest on the first day of the experiment and an identical posttest on the last day of the experiment, spanning approximately 12 days of instruction and practice.

To examine group differences, we used a two-experimental-condition X three-school ANOVA with students' gain score on the assessment as the outcome variable. We found a significant main effect of experimental condition (Figure 5), with TechPALS students learning more [$F(1,155) = 4.08$, $p < .05$]. In each school, the effect favored the TechPALS condition, but the effect size (Cohen's d) ranged from 0.14 in School 2 and 0.17 in School 3 to 0.44 in School 1. Our observational data were consistent with our design premise – TechPALS would work by increasing student collaboration and improving feedback. Behaviors compatible with collaborative learning occurred significantly more frequently in the TechPALS condition. These include reading a problem aloud, asking a mathematical question, giving an explanation, making a collaborative move, directing a peer, and disagreeing with another student. Although our initial research with TechPALS produced promising findings, additional work is needed to increase the quality of the technology, provide better curriculum materials for teachers and students, and train teachers so they can enact instruction that integrates concepts and procedures.

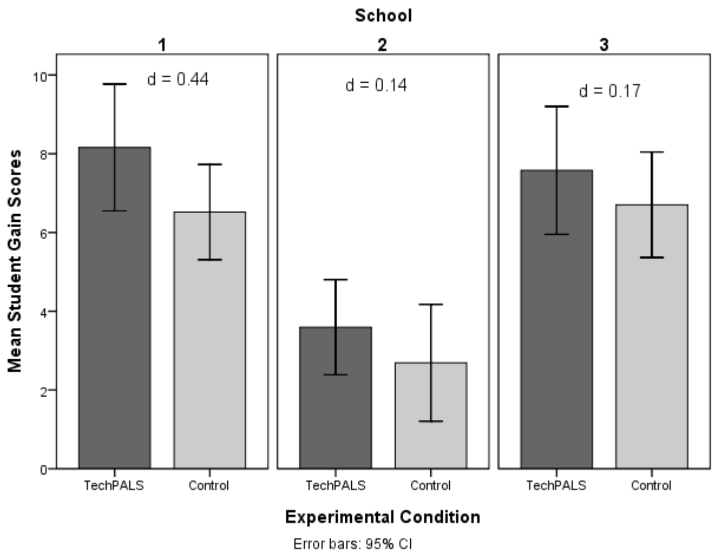

Figure 5. Main of experimental condition on students' scores for fraction knowledge between the pre-test and post-test, in each of three schools.

Although the experiment found an effect, our observations also revealed some disappointments. In particular, we found that the textbooks used by the schools presented concepts very poorly. Further, the textbook presented conflicting procedures for slightly different types of problems. We also observed that teachers' presentations of fractions topics tended to focus only on procedures. We observed students becoming confused while giving explanations to each other during the collaborative activities and inferred that students could not be highly successful in collaborative learning if neither their textbook nor their teacher provided them with a conceptual basis for the mathematics. Further, we still felt the technology was too expensive and fragile for large-scale use; the handheld devices we were using cost about \$300 each and frequently broke or malfunctioned. For the same money, we felt small laptops would be a better value or that custom hardware (ala the "LeapFrog" commercial product) might be more robust. We have proposed additional design phases that would continue to focus on packaging of CSCL in a broader context – we plan to develop all the textbook materials, teacher training, and technology for use during the teaching of rational number in two consecutive school years – and would further refine the technology for greater scalability.

Discussion

Our second step required extensive re-design. Most of the changes we made were broadly contextual, not tightly related to the collaborative activity. For example, we refined our specification of target schools, adopted a more appropriate assessment measure, and specified in more detail how the CSCL activity would fit into a larger unit of curriculum, instruction and assessment. We also added training material so ordinary classroom teachers could take more ownership of the CSCL portion of instruction. In particular, we tightened the Cooperagents training materials and spent more time with teachers describing how their presentations should interleave with CSCL-based practice sessions. Some additional time was spent refining the Eduinnova tool and activities. It is important to note that the majority of our effort was contextual and not specific to the technology.

Whereas in the first year results had been mixed across schools, in the second year we now measured learning gains in favor of TechPALS in each of the three schools. Further, our observational measured showed that desirable collaborative behaviors were present in the TechPALS classrooms and not in the computer lab classrooms. This supports the conclusion that this iteration of TechPALS was an “effective CSCL practice.” Nonetheless, our results also suggested that further improvements would be possible by including more contextual elements in the classroom module; in the future we plan to focus on rewriting the textbook, providing more teacher professional development and further refining the cost and reliability of the hardware.

Conclusion

At the beginning of the TechPALS study, we envisioned our design space to be focused on building and testing a CSCL tool. Our pilot year of work dissuaded us from this naive notion and we quickly re-envisioned the design space to encompass a broader practice of implementing CSCL. Only by attending to non-technological aspects of our classroom module, such as the school context with its expectations of student behavior and teachers’ specific curricular sequence plans, were we able to address factors with significant effects on student learning. The TechPALS experience provides evidence that to develop effective CSCL practices, we must expand our design focus beyond CSCL tools and activities.

In particular, we have come to conceive of designing effective CSCL practices in terms of a “curricular activity system.” At the heart of this phrase, we focus on the design of good collaborative activities. We found that Consensus, Exchange and Aiming Between each had good qualities for encouraging students to work collaboratively on mathematics problems. In our broader view, activities are contextualized by two adjacent phrases. Integrating CSCL activities with *curriculum* is important, because curriculum is at the heart of how schools allocate time to activities. Unless a new activity targets important and difficult curriculum content, it is unlikely for teachers to use it often. Further, deeply considering curricular goals (in our case, how to support student learning across a matrix of concepts and procedures) influences the choice and design of particular CSCL activities. Further, we believe it is important to think of CSCL activities in the context of a larger instructional *system.* In the case of TechPALS, this system included paper-based training materials to introduce teachers and students to desired collaborative behaviors, formative and summative assessments, paper-based group challenges that encouraged students to see the value in helping each other to learn, and teacher professional development. To go from CSCL tools to effective CSCL practices, we recommend that innovators focus on the complete curricular activity system, and not just the collaborative activities.

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The Spellbound Ones: Illuminating Everyday Collaborative Gaming Practices in a MMORPG

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Abstract: A common argument about computer games and learning is that the commitment gamers have might be transformed and used in educational practices. In order to unpack gamers' commitment, the present study investigates collaboration in a Multiplayer Online Role-Playing Game (MMORPG). It investigates gamers' practices in order to expose their everyday gaming activities and knowledge domains. Drawing on detailed descriptions of *team gaming practices*, the paper highlights that gamers' of MMORPGs are hands-on experts in handling a game interface. Their expertise is about *skilled stances* tied to *gaming structures*. Also, gamers are members in *certain* communities and adhere to both community specific epistemologies and to generic ones. These gaming stances are from certain educational approaches difficult to make-sense of, while gamers' commitments in other perspectives become means for learning. Lastly, in relation to MMORPGs and education, a neglected issue concerns social pressure in gaming communities, resulting in various forms of participation.

Introduction

Millions of gamers in many parts of the world spend their leisure time in *Massively Multiplayer Online Role-Playing Games* (MMORPGs). These games have been described as social worlds facilitating tightknit communities (Nardi & Harris, 2006; Steinkuehler & Williams, 2006). Gamers involved in such communities need to manage generic social skills. These social skills can be connected to issues of language (for example a Scandinavian player is required to use English to communicate with other players online and when reading the textual features of the game) and to issues of discourses (cf. Steinkuehler, 2006). Gamers of MMORPGs use specific discourses, where abbreviations and terminologies have evolved over time (cf. Moore, Ducheneaut & Nickell, 2007; Steinkuehler, 2006). A common form of online game discourse is *leet*-speak; a language form that originate from practices of chatting. Another form of game discourse is tied to the practice of role-playing. Here the gamers speak as if they were fantasy characters. Role-playing discourse is a subculture only performed in certain communities in MMORPGs (Copier, 2007). Both leet-speak and MMORPG role-playing are practices where the gamer takes a certain social position and becomes someone on the online arena. Drawing on ethnographical accounts of gamers' everyday gaming activities, the aim of the paper is to discuss gamers' collaboration practices and skills in relation to MMORPGs as educational arenas.

The fact that gamers exhibit commitment while engaging in activities related to gaming have made the field of education pose questions whether gaming and games have something to offer. Especially since educational systems are under pressure to develop educational reforms that will make students more interested in science (cf. Steinkuehler & Duncan, 2008). In relation to this background, the potential of computer games are glanced at (cf. Gee, 2003). In line with this reasoning, MMORPGs seductive power can be seen in relation to two learning metaphors, that of learning through participation and learning through acquisition (Sfard, 1998). Gamers participate in social game worlds where building an online identity is a major motivational mechanism (cf. Linderoth & Bennerstedt, 2007; Taylor, 2006). But MMORPGs are not only powerful identity brewhouses; they are also *knowledge domains*. For example, a gamer need to reason why an enemy encountered in the game is too difficult to handle. This can be due to the fact that it needs several gamers' joint strength to accomplish, that the gamer's virtual embodiment (i.e. *avatar*) have too low level (experience), or have insufficient equipment or that the player lacks skills in controlling his or her avatar. Seen in this light, the game structure forces the gamer to become knowledgeable of the underlying mechanics of how the game works and to manage various skills in order to proceed.

One dream that some educational researchers have is to make students as engaged in the context of schooling as gamers are of activities related to their online game worlds (cf. Barab, Thomas, Dodge, Carteaux, & Tüzün, 2005). Steinkuehler (2006) argues that MMORPGs are sandboxes for educational researchers where they can study "naturally occurring, self-sustaining, indigenous versions" (p. 50) of online learning communities. However, a recurrent theme is to separate learning communities to what is referred to as *formal* and *informal* practices. According to Hung, Lim, Chen and Koh (2008) there are three fundamental differences between them. Firstly, formal practices are subject to assessments of performances. Secondly, there are totally different motivations for participation, where formal practices are built on extrinsic aspects while informal practices rely on intrinsic phenomena. Thirdly, according to these writers, formal practices miss out on identity formation, whereas in informal practices this even spreads to other practices that the member gets involved in. In relation to this division of formal and informal practices, gamers' leisure practices in MMORPGs are in need of modification. Yee (2006) points out that gamers of MMORPGs spend an average of 22 hours a week online, and that this form of media consumption can be related to paid employment. Following this reasoning, the author raises the question if playing MMORPGs concerns what we in general terms consider to be play and fun, i.e. what people do in leisure activities and feelings of enjoyment. Instead another picture emerges where social pressure, i.e. need for solidarity, group pressure and status seeking, is one major mechanism that explain why gamers' play for so many hours and why they become committed to engage in these game worlds (Linderoth & Bennerstedt, 2007). One example of this is shown below. Peter, a *World of Warcraft* (Blizzard Entertainment, 2004) gamer explains how group pressure made him spend more and more time online. The gamer had a major role in the community, the *guild*, he was involved in. Peter's avatar had an important role, a so called main *tank,* in his guild's organized team activities.

> With the Warrior I was built so I could tank. As a result I felt forced to tank all the time. I was like the most important person in the guild. It was really tough. I was always needed. I had to be there every night. I was given first pick of all the good things so I felt I had to take part, like in gratitude, otherwise I would feel guilty. It felt like bad form not to be there. (Linderoth & Bennerstedt, 2007, p. 46)

If we assume that gamers in MMORPGs are involved in a highly influential and effective learning environment, the question not only *how* they learn but also *what* they learn when engaged with these systems arises. Furthermore, in order to make hypothesis about how one practice could influence another, the informal to the formal and vice versa, we need to be aware of what constitutes these practices. Dewey (1985) points out that in order to criticize a specific educational order, we need to grasp what specific norms and values that exists, the so called *social ideal*.

> Since education is a social process, and there are many kinds of societies, a criterion for educational criticism and construction implies a particular social ideal. (Dewey, 1985, p. 105)

The idea of social ideal as presented by Dewey is means as thought piece for imagination that link the 'worlds' of schooling and online gaming. In this paper, the notion of social ideal is working in line with what Garfinkel (1967) points out that people in their everyday conduct have *commonsense knowledge* of activities that for them, the members of such practice, are seen as *commonsense activities*. By taking the interest in gamers' *methods*, how they accomplish practices relevant for them, we make visible gamers' skills and competencies that they enact in their everyday, routine gaming practices.

On a general level, it is possible to talk about social ideals in MMORPGs by summing up indications from previous research, namely that the major time investment and participation stems from social pressure tied to *tasks done in collaboration with others*. Hence, the social gaming activities in MMORPGs shapes collaborative problem solving practices that Steinkuehler (2008) argues are to be understood as *cross-functional teams*. Following this reasoning, we go further and unpack gamers' interaction in order to more closely examine what gamers are skilled and competent in when working in teams. As MMORPGs consist of many kinds of online societies, screen-captured video data from *World of Warcraft* is used in order to analyze two teams' ways of accomplishing coordination when engaged in gaming activities. On an interactional level, the gamers' collaboration shows that their expertise can be understood as orchestrating an ensemble. The participants manage to coordinate each other through talk in chat and actions by means of their avatars. Drawing on the empirical accounts and previous research on social pressure present in MMORPGs, the paper indicates two overlooked phenomena in relation to learning and formal practices. Firstly, the expertise involved when mastering a game interface and the skills required when coordinating and assessing other gamers' performances online. Secondly, the empirical examples make visible that gamers are attuned to different social ideals tied to different communities' ways of talking (and, actually, walking by means of the virtual body). Finally, these findings are used as point of departure to discuss arguments concerning learning outcomes and processes by means of MMORPGs.

Method

This study uses an interaction analytic and ethnographic approach in order to investigate cultures within MMORPGs. The analytical point of departure is interaction analysis as presented by Jordan and Henderson (1995) as a way to explore gamers' team-oriented practices. The study is grounded in screen-captured video data. From this material, questions concerning what players do and how they go about and make-sense in-game when collaborating and coordinating with others are raised. In this way, the study adheres to a tradition that scrutinizes participants' sense-making by means of, among all, their talk, gestures, the surrounding and body-orientation (Goodwin, 1994; Goodwin 2000). However, instead of physical bodies in front of computers, the examined setting is the *game landscape* with its text-typed talk in chat windows and actions performed with the virtual body, the *avatar* (for more elaborated accounts, see Bennerstedt, 2008a; Bennerstedt, 2008b).

The gathering of empirical material is informed by ethnography (Hine, 2000; Moore, et al., 2007). By participant observation in various European *servers* of *World of Warcraft* we have reached a gamer perspective. The empirical material in this paper has been video-recorded by the second author. Out of several hundreds of hours of playing time only a fraction has been video-recorded and out of 90 hours video data from three MMORPGs, 20 hours are from *World of Warcraft*. The recorded material contains team related gaming practices and role-playing practices. In relation to ethics, the paper has two approaches. As we are interested in actions of collaboration online, we are not interested in the players' personae outside the game context. In the first example, where players are strangers to each other and grouped together for a *short period of time*, we adhere to praxis of Moore et al. (2007). They mark out a research strand that is interested in investigating gamers' talk-in-interaction in naturally occurring activities. The recorded members in the team are not aware of our in-game personae as researcher and "we were not aware of the real-world identities of the players, only their in-game pseudonyms and personae." (Moore et al., 2007, p. 269). As the second example concern players that are familiar to each other, they are aware of us as researchers and, hence informed about the video-recording. All the names of the players' avatars have been changed.

The screen-captured data have been transcribed from practices stemming from conversation analysis (Sacks, Schegloff & Jefferson, 1974). Also, it is inspired by sequential art (McCloud, 1994) as has been used by Ivarsson (2007) and Lindwall (2008). In order to situate the players talk in chat (these gamers do not use voice-chat) with actions in the game landscape, the paper relies on support of images taken from in-game situations. Some objects in the images have been highlighted by means of an image editor. Also, the typed talk in chat is cut out and put in speech balloons that *sequentially* outline gamers' text-typed talk, to be read from the left to the right, coupled with images relevant for the participants' subsequent actions in the game landscape.

Findings

Team Roles in World of Warcraft

As setting to investigate gaming activities we selected the MMORPG *World of Warcraft*. This online game was released in 2004 and in late 2008 it had about 11 million, monthly paying subscribers. *World of Warcraft's* fantasy world has a graphical interface where, for example, the chat window is situated in the bottom left (see Figure 1).

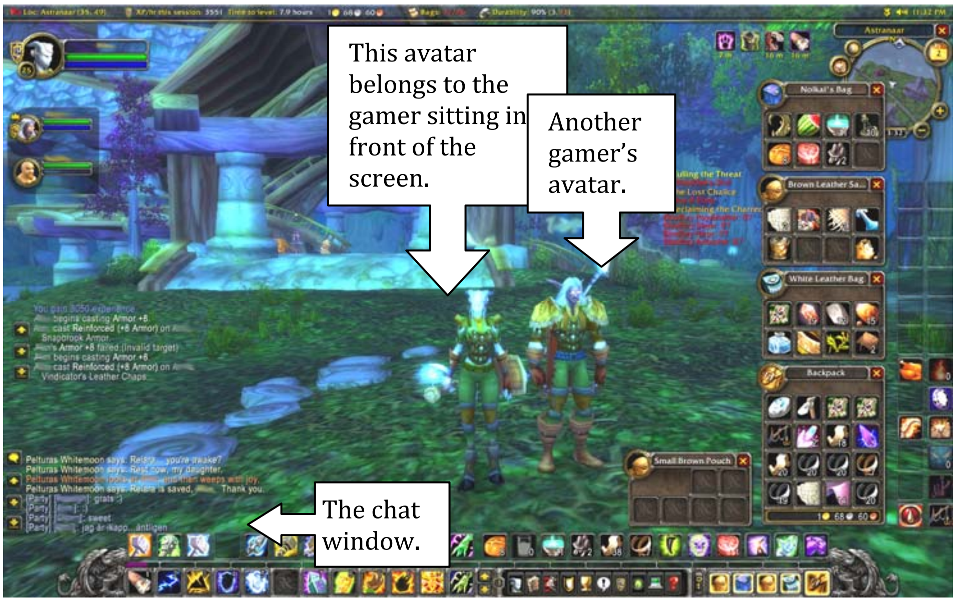

Figure 1. An example of World of Warcraft's customizable game interface.

World of Warcraft involves a 3D-gameworld, where gamers interact with the game system and with other gamers in various ways. A gamer starts by choosing and customizing a character. In this creation process the gamer chooses the appearance, the name, but more important, the specific *class* (for example priest, mage and warrior) the avatar should have. The avatar starts from zero and by doing various types of activities and quests, for example, killing monsters (*mobs*) in the game or by gathering objects, the player gain *experience points* which makes the avatar evolve (i.e. gain higher levels and skills). Furthermore, as *World of Warcraft* is a multiplayer game there are various supports for interaction between players. Various chat channels exist and gamers can also use voice-chat to support player interaction. *World of Warcraft* has an interactive structure that in many ways forces gamers to join groups and to play together, but at the same time there is plenty of ways to play solo. However, what have drawn most people into these game worlds are the social side of the game; either by playing alone but being able to socialize with other gamers through chat or by "seeing" others avatars (Ducheneaut, Yee, Nickell & Moore, 2006), or by actually being involved in team related gaming practices.

MMORPGs are built on differentiating players' avatars in ways in which different functions are connected to what the player selected when she or he created the avatar in the first place. Thus, gamers in groups have different roles depending on their avatars classes. There are three major roles in a team; the *healer* takes on the function of healing other players avatars, the *damage dealer* is an avatar that can make a great deal of damage to mobs, and the *tank* is an avatar that has a strong and solid armor to stand against mob attacks. Several classes are hybrids that make it possible to shift between different roles.

Team Gameplay as Task Related and Recurrent Periods of Action

As MMORPGs are computer games, gamers engage in gaming practices alone or in teams. Engaging in gaming practices are often glossed as *gameplay,* thereby implying that the gamers interact with the computer *game rules* in certain ways (Juul, 2005). This paper focus sequences where gamers both interact with the game rules and collaborate with others in small groups (in *World of Warcraft* this is known as a *party*, a group with up to five members). There are various reasons why players team-up in such groups to engage in gaming practices. One central motive is that gamers have specific *tasks* that require the combined strength of several avatars (tasks often stem from so called *quests* that the game provides). Other causes is that gamers team-up to aid others just for the pleasure that others are in need of help and expertise (cf. Ducheneaut & Moore, 2004); to stage role-playing events in, or they may, as the gamer Peter above described, have feelings of group pressure to take part.

When engaged in team related gaming practices in MMORPGs, there are recurrent and nested periods of actions involving various practices. Firstly, the *grouping period* concerns issues of deciding to do a joint session with others, negotiating task objectives and meeting up with the team on a specific location in the game world. Secondly, in *the way forward period* the gathered group then starts moving forward with their avatars in a certain direction. Thirdly, as the game landscape that the gamers are steering their avatars in, hold troubles and threats they will be forced to go into fight with enemies of various kinds and numbers. When this happens the gamers can be described to be within the *fighting period*. The fighting period can be initiated by one of the gamers by mistake, i.e. coming to close to a mob that then senses the gamer's avatar and starts hunting the avatar (a response from the game system). Another way, which will be illustrated below, is to use certain abilities that different types of avatar classes use in order to manage several mobs in an efficient and safe way. Lastly, there is the *looting and resting period* after the mobs have been eliminated. To loot means the activities that take place when the gamers share the treasures that the mob holds. Furthermore, in some cases, the gamers' avatars need to be 'restored' when they have consumed too much energy (i.e. mana or health) and therefore they need to be regaining strength in certain ways. However, if the gamers fail to defeat the mob/s they will be in the grouping phase again due to the fact that their avatars will be resurrected to a place that is further away in the game world (this can be overcome by resurrection abilities that certain avatars are skilled in or have in-game objects that holds such functions).

In the sequences below, we will follow two groups of players that are in front of mobs that stand in their way in their *route forward*. In this way, the gamers can be seen as situated in the way forward phase that passes over to practices belonging to the fight period.

Collaborative Gaming Accomplished Online

The empirical sequences investigate the ways in which two groups coordinate their actions in order to battle against computer-steered enemies. For an outsider of MMORPGs, the first sequence illustrates why it is difficult for novices to participate in them because of their uses of unfamiliar words in an alien landscape. In the second sequence, the gamers are doing what the gamers did in the first example, but with a different way to talk that belong to the ways a minor subgroup act online. Both the first and second example show experienced gamers, but with different ways to coordinate the central task of taking down mobs. In both examples, the avatars' that are labeled Colt is steered by the second author and the events are video-recorded from the view that the author have in the course of action.

Coordination Work in Team Gameplay

The team in the sequence below does not know each other. They have come together for the purpose to proceed into a specific dungeon in order to complete certain quests. When we enter the sequence, the gamers have played for a couple of minutes and have discussed which quests inside the dungeon that is going to be pursued in which order. They have met and fought single mobs on their way forward. In the sequence below there are three mobs standing still in a circle. In the first frame, in Figure 3, the three mobs are seen in the upper left corner and the five gamers' avatars are facing towards them. The mobs stand in the avatars way on the path they are following in the dungeon.

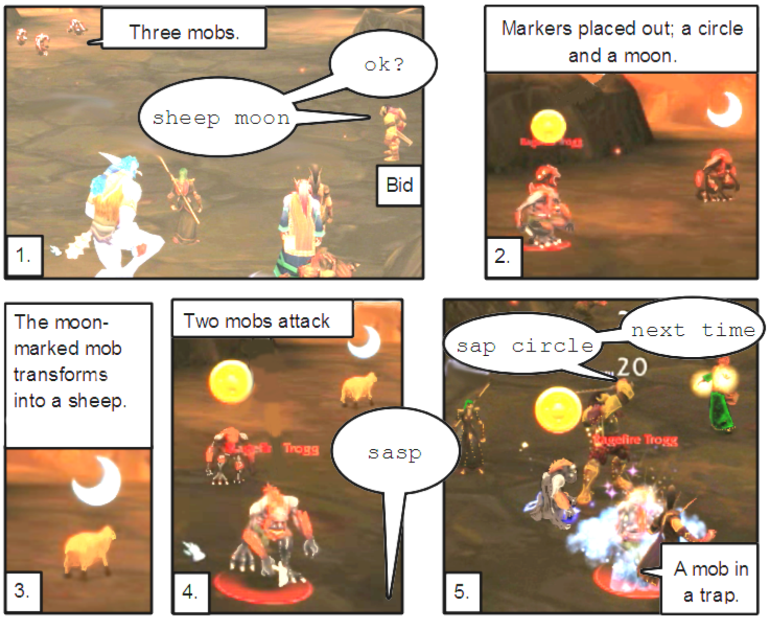

Figure 3. Five gamers coordinate and assess their in-game actions.

One of the gamers who steers the avatar named Bid starts to instruct the group by typing in the chat window "`sheep moon`" and thereafter "`ok?`". Subsequently the gamer puts out visual markers on the mobs; firstly on the rightmost mob that gets a moon shaped marker above its head and after this, the mob closest to their avatars is marked with a yellow circle. As a response to the instruction, Mute – the gamer who holds the avatar which has the ability to do the thing Bid asks for – *sheep* the moon marked enemy. This is seen in the third frame, where this enemy is transformed into a sheep which immobilizes it for a couple of seconds. However, when doing this, the other enemies notices them and attack – this is a game mechanic function that means that mobs have an area around them that senses avatars doings in the game landscape in various ways. In the second after, in Frame 4, Colt asks for a *sap* (in the event of actions the gamer misspelled). To *sap* means to immobilize an enemy by putting it to sleep. Game mechanically, a sap has to be accomplished first, because sheep can be managed after, but not the other way around in a particular battle. Hence, Colt makes a request to the other gamers by this remark, meaning that the correct order to do their coordinated attack is a function that his avatar has abilities to do (i.e. to sap). Colt has in this order of tasks no possibility to sap as the mobs are on their way.

In the last frame, the two mobs have reached the group and the team members start to fight the mobs (i.e. by pressing keyboard buttons that are tied to various actions that lower mobs energy that is dynamically updated and observable in information bars in the game interface). In this frame we see that another gamer in the group have made an *escape action*. The gamer used a skill that his or her avatar holds, this ability makes it possible to place out a trap in the direction the mobs attack. A mob that is trapped makes it impossible for it to reach the group. In this way gamers *continuously* unarm mobs with various abilities while dealing out damage. By trapping the unmarked mob, the gamer can focus on the third mob – the one marked with the circle. Also, in the last frame Bid acknowledge what Colt pointed out by repeating and clarifying the instructions by saying "`sap circle`" and "`next time`", meaning that in the next coordinated attack they will first sap the mob that gets a circle above its head and only after this is completed to use the sheep ability on the moon marked one.

This sequence of coordinated team activity is over in 20 seconds. The gamers continue in the dungeon and adjust to their instructions and make themselves visible for being knowledgeable of the game terms functions in the gaming events. Thus, the gamers can by these typed instructions, game terms and in-game actions decide that the other team members, who they do not know, are skilled in how to handle their avatars and how to act with them in collaboration with other avatars that have different abilities. The gamers are practitioners of a game interface that makes them accountable for their actions – the member Bid instructs Mute, who responds by acting with the avatar, while Coly both assesses Mute's actions and Bids instructions. In this way, this type of practice illustrates assessments of participants' doings that in some ways contrast Hung et al. (2008) argument of informal practices. Although the assessment is not related to grading as in schooling, but tied to aspects of being seen as a competent gamer that can be a door-opener for invitation in further jointly activities. For the gamers', exhibiting skills and graceful coordination are means of success. A successful gaming event is for these gamers about proceeding in an efficient way in the game landscape. And with the success of the collaborative tasks comes phenomena of satisfaction and enjoyment.

Role-Players' Work in Team Gameplay

The second example takes place on a role-playing devoted *World of Warcraft* server. It must be stressed that the majority of gamers on role-playing servers do *not* adhere to practices defined as role-playing (Copier, 2007) but are more in line with doing team collaboration as seen in the first example. In the excerpt below, there are five other gamers involved in a different dungeon, called Sethekk Halls. In total this cave takes about two hours for an efficient, balanced and competent team to complete.

The gamers in this excerpt are more or less familiar with each other. In the sequence, we will see how this group uses role-playing discourse and at the same time engages in gaming practices. Gamers involved in these specific linguistic practices are termed to be *in-character*. This means that gamers use various make-believe practices by means of what can be understood as a virtual *puppet*, i.e. using the game interface such as the chat channels and avatars actions to act out a fantasy character (Bennerstedt, 2008a). One example of these practices is to alter between running and walking with the avatar. Hence, the normal way of moving with the avatar is to run. This stems from the fact that online game worlds consist of huge areas that the gamer wants to reach as fast as possible. As the avatar does not become tired of running or walking, the normal settings default of moving in the game is set on running. Therefore the gamer needs to push a specific button in order to walk with the avatar. On role-playing servers walking means something more than just moving forward in slow pace. Instead, this is a common way to show that you are engaged in acting as a fantasy character. Just before the sequence below, two of the gamers *walk* forward with their avatars, moving slowly nearer the next group of mobs that stand in their route forward. If the gamers in the first example had walked with their avatars they would have been questioned about why they proceed so slowly forward. While in the case of this group of role-playing gamers', this is something belonging to how they go about doing gaming in teams.

Figure 4. Five gamers engaged in role-playing in a collaborative game task.

When we enter the situation in Figure 4, the gamers' have played for about 30 minutes. In frame 1 their avatars are standing as in the first example, in front of five moving and stationary mobs. Instead of instructing by using game specific terms, narrative work is done to coordinate the gamers' doings in the game interface. In Frame 1, the gamer acting as Rose types in the chat window "`I spy a shackle nearby`" to direct their attention to the mobs in front of them. The term *shackle* is related to a talent that Rose's avatar holds that are working in similar ways of that of sap and sheep. After this she types in the chat interface what is termed an *emote*. An emote is a textual description of what the avatar thinks, does or the like. The gamer's typed emote says "`Rose rubs her bandaged hands lightly together.`", to illustrate that the fantasy character Rose, that the gamer is acting as in the game landscape, is looking forward to encounter these mobs. The gamer steering Velvet type "`Hm…`". In the following seconds the team put up, in silence, visual markers on some of the enemies (see Frame 2). In the third frame, they start to negotiate who is going to do the first action towards the mobs. The female avatar Velvet continues by asking "`Azon would you?`" and Azon answers "`Sure.`". What is referred to by the gamers is what was discussed in the first example, namely to *sap*. Azon is then an avatar that has the ability to sap mobs. To sap a mob implies that the avatar sneaks closer to a mob, using certain abilities to avoid get detected, and then uses the sap function to put the chosen enemy out of action (Bennerstedt, 2008b). However, in the last frame, Azon asks another gamer, Colt, to do this with the remark "`Want to have the fun, Colt? Your brightly-glowing swords are rather less brightly glowing than mine I think.`" What the gamer steering Azon is commenting on is that the avatar Colt also has the sap function, even more so, that Colt has better equipment (referred to here as his swords) than the avatar Azon that makes Colt being more suited in this situation to perform the sap on the marked mob without getting detected by the mobs in the surrounding. For the players, graphical and textual information in the game interface of their avatars makes it possible to *reason* in mathematical terms and, hence judge whose avatar have the best chance to accomplish a certain action at a certain time and place. Gamers online are accountable for evaluative epistemologies (cf. Steinkuehler & Duncan, 2008), but this subgroup also needs to account to conceal this evaluation activity by role-playing discourse. Colt then proceeds with the agreed way on who is going to do what by performing and executing the sap function as a starting action to their coordinated fight. For these team members, the yellow circle is commonsense knowledge to use to point out the mob that is going to be sapped; it is not needed to be mentioned. Subsequently, the gamer named Colt steers the avatar towards this marked enemy in order to execute the actions.

These gamers chose to engage in this more demanding ways of speaking based on social values from certain role-playing ideals that only a minor fraction of players online adhere to (Copier, 2007). The gamers' narrative work (see also Linderoth, 2008) is here used to coordinate the players' attack and if contrasted with the previous sequence, this sequence illustrates the ways role-players attend to and conceal the game mechanics that are structuring their coordination activities. For these role-players, gaming in teams does not only concern the success of the tasks, but being able to make *aesthetically* appealing formulations, thereby constructing themselves as skillful role-playing actors.

Discussion

This paper has investigated team members' gameplay practices in their everyday activities to make visible their domains of knowledge. The practices gamers have make visible what *they* see as relevant *objects of knowledge* (cf. Goodwin, 1994), such as the use of the terms *sheep* and *sap* in particular situations. In and through instructions by means of utterances in chat, gamers accomplish collaboration and coordination in the perceptual field of online gaming. The everyday gaming practices we have investigated concern gamers planning and execution of actions by means of their avatars in order to take down a group of mobs. As a general claim of the two different ways to instruct each other, the empirical examples show that for outsiders of these game worlds, a) the first team use words that are either unheard of outside or used in ways that are unfamiliar in other contexts, b) the second team use narratives that cover the complexness of the underlying computer game mechanics, c) gamers coordinate their avatars in ways that correspond to the underlying game structure.

Continuing on Dewey's argument that in order to criticize a society, you need to be aware of what social ideals underlie that society, it is possible to expose some additional ideals in MMORPG societies. One neglected ideal is that sitting in front of a computer screen collaborating with others by means of a game interface *fosters* ways to act online. In relation to previous studies of collaboration online, an often overlooked issue is the reported misunderstandings and problems that arise between participants in chat conversations (cf. Fuks, Pimentel & Pereira de Lacuna, 2006) and when coordinating virtual bodies in 3D environments (cf. Hindmarsh, Heath & Fraser, 2006; Moore et al, 2007; Moore, Gathman, Ducheneaut & Nickell, 2007). The team members in this study accomplish collaboration with the use of game terms, in-game pointing devices and actions with their avatars. By means of these resources, collaboration is managed in an efficient and smooth way, because they show in their *interactional work* that they are familiar to these activities. Although for newcomers to this domain it will take time to become skilled in the ways to speak and act online as discourse not only *differs* from the outside world but also among communities in MMORPGs.

The gamers' engagement and effort are in the analyzed sequences about expertise in complex game mechanics coupled with team roles. The first group can be seen as experienced gamers with the aim to achieve a handy and efficient team. They are skilled in instructing via game specific terms which member is going to do what in what order. While the second group's practices illustrate expertise in role-playing in order to be *seen* as steering a fantasy character in a fantasy world, but at the same time the group assesses and instructs each other in the identical way as the first group do. These forms of expertise are tied to identity formation understood as being knowledgeable of certain ways to be and act. Gamers achieve roles online in ways that are seen and heard in-game by others as such (cf. Bennerstedt, 2008a). The coordination practices between the gamers make them accountable to be skilled citizens who know how to interact in teams in proper ways. They have achieved what Goodwin (2007) terms *epistemic stances* relevant for gaming practices. The ways they use game discourse relevant in *World of Warcraft's* game universe and are able to see the order of actions based on the members' avatars different abilities are commonsense knowledge and activities in this domain. For them, it is *abnormal* to not know what it means to sheep or sap. As computer gaming is about making sense of an interactive structure (cf. Juul, 2005; Linderoth, 2004) computer gaming *online* adds the layer of online social order. In this way, gamers of MMORPGs are practitioners with expertise that they are contested to have that also is tied to the type of community the gamer is attuned to in the MMORPG, i.e. various *online social ideals.*

Implications for MMORPGs as Scenes of Education

In relation to the CSCL field's interest of describing meaning making practices (cf. Stahl, Koschman & Suthers, 2006), this study present MMORPGs as powerful interactive structures forcing players to team-up that create collaborative arenas for contesting epistemic stances. The studied sequences make visible that a major object of knowledge (Goodwin, 1994) in team gameplay is that of being skilled of *seeing events* in the game interface and being able to communicate and direct attention to phenomena of game mechanics in the course of action.

Although not yet realized, one powerful scope for imagination is to develop distinct MMORPGs for specific subject matters to be seen as online learning brewhouses. A gamer's role in a group can be translated to concern a totally different subject matter than *World of Warcraft's* knowledge domain but still utilize its gameplay structure. For example, we can take a natural science subject, the human immune system, and have as virtual setting the circulatory system. Gamers of this virtual system might select an avatar with particular functions based on various cells and proteins, that is, different white blood cells and antibodies that we have in our blood. The system might be constructed to force players to collaborate with each other to fight various diseases and viruses, playing on either the attacking side or the immune defense side. Since the immune system is a very complex issue, the system might as well become rich and complex.

However, there are several phenomena to consider. As Schrader and McCreery (2008) point out, the game designers of *World of Warcraft* advance and change the game's content and mechanics *every other week*, making this environment unstable, and hence, it differs from school domains of for example mathematics, making notions of expertise in MMORPGs an *ongoing project*. Furthermore, to let the made-up science MMORPG become a game and not a simulation, the gamer needs to be able to make informed choices on what is designed to have valued outcomes (Linderoth, 2004) that inevitably restrains the content and interaction in the science MMORPG. Nevertheless, if we assume that an educational online game is done in this delicate design process, we can continue to relate to the empirical examples above. In relation to the first one, this is an example of everyday online game behavior. For these players, they have probably played in this area several times before and played in groups of this kind hundreds of times. They know the game interface by heart, how to work in teams and how to be in a social situation with other gamers online. As for the immune system game, the gamers need to become used to the interface, get a grip of the underlying mechanics of the game structure, that is, what kind of cells are there and their function in *this* virtual setting and so forth. Following what the gamers did in the empirical examples, the natural science gamers will instruct, when coordinating their effort, each others in the similar way. For example, asking a member to eliminate a cell named hepatit B virus by typing "`rel ant`" and "`neu`". The first utterance can be seen to mean release a specific antibody function on the area and the other to neutralize the virus cell. The players then will have to drill themselves in order to coordinate their attacks as well-functioned teams. However, the drilling will be about *coordination*, to get things done in the most optimal way in order to proceed forward in the game landscape. This means, that in order to have students as passionate about a natural science MMORPG, the game must be about complex team actions that need expertise for mastery which can be miles apart from concerning issues of grasping how the immune system works in human beings.

Returning to the accomplishment of becoming someone online; gamers' appropriation of the ways online citizens speak can be related to goals of scientific reasoning and "to know relevant content in ways that would be revealed on measures of scientific achievement." (Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007, p. 60). When involved in gaming actions in the made-up science MMORPG, the words and the ways science-gamers will talk will not look like science discourse (Arnseth & Ludvigsen, 2006), but like *gaming discourse*. By this implying that in order to let students become MMORPG gamers, they will strive for expertise based on a language that the majority of gamers in MMORPGs adhere to online – the *efficient* instructions and not talking 'as' someone else as the case of the minor subgroup of role-players. From a distance, the made-up natural science MMORPG can be understood to blend the two learning metaphors of that of acquisition and that of participation. But as have been illustrated, one main activity in MMORPGs is about drilling of petite gaming actions and to coordinate who is going to do what, using what functions in what situation. Hence, the gaming practices examined make visible that gamers' main objective are about skills of coordination.

Nevertheless, if we assume that virtual game worlds are used in educational practices in schools with the aim of, for example, acquisition of English for a Scandinavian student in *World of Warcraft* or teaching science with the made-up game world, we must ask what "*particular* social ideal" (Dewey, 1985, p. 105) underlies such engagement. Are we to pursue the goal of keeping students busy as of being committed and interested in anything in school, hoping that they will gain knowledge of *something* (for example English)? Following this ideal, the notion of participation in MMORPGs work as *gatekeeper drugs* (Steinkuehler, 2008) to activities valued by the non-gaming society, i.e. skills and competencies relevant outside MMORPGs, and to acknowledge that spending time online foster ways of reasoning that is valued outside these gaming worlds (cf. Barab, Thomas, Dodge, Carteaux, & Tüzün, 2005; Barab, Arcici, & Jackson, 2005; Steinkuehler & Duncan, 2008). For example, Steinkuehler and Duncan (2008) studied gamers posts in online discussion forums where issues related to *World of Warcraft* where debated and found that they were engaged in scientific argumentation, in this way the authors argue that participation in MMORPGs can foster scientific habits of mind. A related question is to ask if we want students to be knowledgeable in *new literacy's*, that is, being skilled in communicating and coordinating in online worlds. Or do we have the goal that the students gaming practices, i.e. mastering the underlying mechanics of the very system implemented, will lead to commitment to and knowledge in a (school) subject matter? Following the last ideal, the imagined science MMORPG will be about an artificial setting with an artificial social community surrounding it (cf. Hung et al., 2008). This in contrast to participating in *World of Warcraft* that concern crafting online identities and developing expertise in gaming epistemologies coupled with social pressures of being 'there' that leads to *sustained* commitment.

The acquisition of school subjects with the aid of collaboration practices in MMORPGs, i.e. practices that are labeled *team gameplay* in the paper, has not yet been attempted. Drawing on the empirical investigation, we argue that such attempts need to consider institutional contexts (Arnseth & Ludvigsen, 2006) as participating in MMORPGs can be understood to foster *gaming epistemologies* that take over other epistemic stances.

In relation to gamers' skills, competencies and commitments, we argue that we as researchers must be explicit about and also study what gamers recurrently *do* online in their gaming practices. Continuing on this, another issue sidestepped from a learning perspective that needs to be discussed concerns the mechanism that influences gamers' passionate involvement in MMORPGs. More specific, the driving mechanism for continued engagement is not always 'fun' or positive as it can be about (negative) group pressure that leads to problematic usage. Hence, MMORPGs falls between the categorization of formal and informal practices as participation in them is not always intrinsic motivated as it can be of the extrinsic character of group pressure. Also, gamers are subjects of 'formal' assessments in the sense that these online societies are tied to evaluations that stem from the game structure and from various communities ways of behaving in 'normal' ways. In this way, MMORPGs become arenas that 'force' learners to adapt, i.e. if the gamer has not yet reached some level of skills that are needed to engage in gameplay, the player will 'fail'. Likewise, if the player is not skilled in the ways to talk and behave online the player will have problems to take part. Although this can be overcome by being instructed by helpful online citizens (cf. Steinkuehler, 2004) it anyhow reveals that these online societies have mechanisms that push and force gamers to adjust (that at times is not unlike structures of schooling).

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Supporting Student Engagement in Simulation Development

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Abstract: This paper presents a small-scale study investigating the use of the MicroWorlds Pro multimedia programming environment as an authoring tool for constructing models, simulations and multimedia applications with students of Senior High School. We implemented two alternate instructional strategies: simulation development from scratch and use of a preconstructed microworld, and observed how the students collaborate and interact with the programming environment. The findings highlight the overall process and the differences in the students' levels of engagement and performance, indicating some special features of the programming environment that contribute to or cause difficulty in the creation of an effective learning environment.

Introduction

The study we report here is part of our effort to extend our experience in designing learning environments that support learning through exploration, expression, construction, meaning negotiation and collaboration. We attempt to gain some further insight into the potential of using the multimedia programming environment MicroWorlds Pro as an authoring tool for constructing simulations and multimedia applications, as well as contributing to the discussion on the main parameters of planning, developing and implementing an effective constructionist approach aimed at engaging students in a cross-thematic multimedia project.

This paper presents a pilot implementation of the cross-thematic scenario "Free fall simulation development" as an open and flexible framework for activities. This scenario combines elements from Informatics, Physics and Mathematics, and places emphasis on building microworlds as models, simulations and multimedia applications as combined projects (Glezou & Grigoriadou, 2008).

Theoretical Framework

Logo-like environments can be used to plan and develop microworlds that offer students the possibility to express and exploit their thoughts, ideas and instincts and support the process of building knowledge by creating learning environments rich in speculation and opportunities for experimentation (Resnick et al., 2003, diSessa, 2000, Harel & Papert, 1991, Papert, 1980).

In recent years, a number of educational research projects have used computer-modeling tools in education and, especially, in science learning (Schwartz, 2007, Wilensky & Reisman, 2006, Dimitracopoulou & Komis, 2005, Teodoro, 2002, de Jong & van Joolingen, 1998). Recent research focuses on further understanding design characteristics of computer-based programming environments which may promote or impede learning with models in science (Simpson et al., 2005, Louca & al., 2003, Louka & Konstantinou, 2002). Learning to formulate, analyze, test and revise models is a crucial aspect of understanding science, and critical to helping students become active, lifelong learners. It is important to study and identify the particular ways that students use computer-based environments that support student inquiry and modeling practices. The true value of modeling emerges when students can elaborate concepts developed in previous modeling activities, in order to deal with more complex modeling problems (Forbus et al., 2001). Preconstructed microworlds are meant to operate as starting points and idea generators for building on them, changing them or decomposing parts of them in order to construct a new artifact (Kynigos, 2006). It is difficult to provide students with building blocks sufficiently powerful to create models, yet sufficiently flexible and transparent to encourage students to question their inner workings (Simpson et al., 2005).

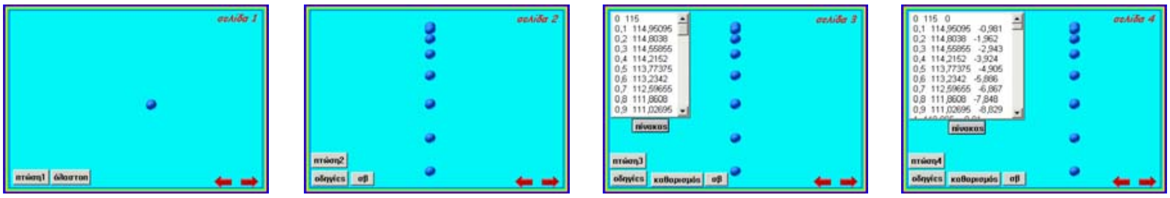
Research Framework

The present study is part of a wider research, which aims to explore the possibility of implementing a cross-thematic educational scenario by using the MicroWorlds Pro environment (Greek version 1.1) as a framework for activities and for a series of lessons. The aim of this research is to bring forward the basic parameters of an effective interdisciplinary constructionist approach, in the level of planning, development and implementation. As an inquisitive hypothesis, we assumed that MicroWorlds Pro is an appropriate multimedia programming environment for the development of microworlds as models, simulations, multimedia applications and combined projects, in the framework of implementing a cross-thematic educational scenario that promotes collaborative exploratory learning. The basic research questions of the particular study are: - Which instructional method supports best student engagement in simulation development: simulation development from scratch or use of a preconstructed microworld? - How do the students collaborate and interact with the programming environment? - Which are the special features of MicroWorlds Pro that contribute to or cause difficulty in the creation of an effective learning environment?

It is a case study that uses ethnographic and action research elements, since the researcher was also the teacher of the class. In the framework of the educational scenario “Free fall simulation development”, after the setting of the didactic aims/targets, we structured a series of lessons in phases; each phase in stages and each stage in distinct steps. Then, we developed a) microworlds in MicroWorlds Pro, b) activity worksheets-lesson plans, c) student worksheets and d) additional teacher worksheets, by making a formative evaluation during their development. The research tools used were the above, as well as the Greek version of MicroWorlds Pro.

We collected data from the researcher’s notes-diary after each didactic hour, the students’ notes-drafts, the filled-in worksheets, the microworlds and final combined projects of the students, as well as from semi-structured interviews of students. Then, the data underwent a qualitative analysis, whose results led to modifications in the ergonomics, the appearance and function of the microworlds, as well as in the gradual ameliorative reshaping of the lesson plan and the worksheets.

The suggested cross-thematic scenario was implemented in the framework of the “Multimedia-Networks” course in two classes of the 3rd grade of A and B Arsakeio General Senior High School of Psychiko in Athens, during the first four-month period of the school year 2006-2007. “Multimedia-Networks” is an optional lesson without written examination, which students of all three orientations (theoretical, scientific and technological) can take up, so it requires special treatment due to the heterogeneity of the students. This heterogeneity has to do with the basic computer skills and with programming skills in particular, as well as with the different cognitive level of the students in Physics and Mathematics. In addition, a significant 30% of students showed reduced interest and negative spirit towards the course. The students were already familiar with the MicroWorlds Pro environment and the basic Logo commands, within the framework of previous lessons (of one didactic hour per class) that had to do with learning the environment’s basic features and with the creation of microworlds by adding cartoons and multimedia elements (e.g. sound, video). The students were separated in small groups of 2 per computer of their own choice. Due to the odd number of the 2nd class, there was also one team with three students. In the present research, which took 6 didactic hours per class, the participants were 2 classes of 9 teams-18 students (8 girls-10 boys) and 11 teams-23 students (14 girls-9 boys) respectively.



a *b* *c* *d*

Figure 1. Snapshots of the “Free fall simulation development” preconstructed microworld.

We implemented different teaching strategies for each class. In the 1st class, the students were asked to build the microworld gradually, from scratch, according to the worksheets, as they refer to the first three phases (A, B, C) of the scenario. In the 2nd class, the students were given a readily made, preconstructed microworld, as it was developed after the completion of the first three phases, and were asked to experiment with it. In the next step, the students of both classes were asked to modify the preconstructed microworld and proceed to the last two phases (D, E) of the scenario. The preconstructed microworld “Free fall simulation development” (see Figure 1) consists of four pages characterized by a gradually increasing complexity that corresponds to the particular phases of the scenario: a) On page 1 of the microworld we have the creation of the free fall simulation (Phase A); b) On page 2 we have the creation of the free fall’s stroboscopic representation (Phase B); c & d) On pages 3 & 4 we have the creation of the free fall’s stroboscopic representation and the exploitation of a table exhibiting the values of time, position and velocity (Phase C). The structure of the evolutionary phases and respective activities was characterized by a gradually increasing degree of complexity and difficulty (Dapontes, 2005). The students would gradually reach a higher level of familiarization with Logo and the MicroWorlds Pro environment, while constructing their knowledge, developing skills based on previous experience, composing, analyzing and expanding codes.

Evaluation of the Application

From the data analysis of this pilot implementation (the application is in evolution so we present only indicative facts here) we should stress the following:

The students showed interest in their interaction with the MicroWorlds Pro environment and remained active during the lessons, especially in the phase where they had to create their own simulations and multimedia applications. Students that were not initially interested in the “Multimedia-Networks” course were motivated and cooperated satisfactorily. Yet there were five groups that cooperated only fragmentarily. The students, in many cases, were enthusiastic after being exposed to the “purely” programming part of the lesson and admitted having a “live” interaction with the environment. While investigating each program in the activity sequence, students went repetitively through a cycle of prediction, modeling in Logo, model-testing and consideration of the limitations of any current model’s scope of application. In their experimentation process, students receive direct feedback from the environment; they negotiate, cooperate, criticize one another, evaluate themselves, take turns in the first and second role, suggest ways of coping with new situations and try out new commands. They become more active and their centre of interest is transferred easily, tracing new exploration paths.

The process had a positive effect on both classes. Actions such as the planning of the desired interface surfaces, the recognition of a command sequence and the definition of a procedure are considered to be indicative of the high level skills and goals’ development, such as the recognition of a procedure function and the definition of new procedures. The repetitive shift between the code analysis and its reforming/extension, which allows the shift from simple to complex and the gradual familiarization with the programming language within the scaffolding process, has proved to be equally effective. During the process of developing the Logo code and of debugging, the questions posed by the students were often fixed and imperative. The teacher needs to proceed in subtle handlings, in order to accommodate the students with no more support than what they need. We observed an increased difficulty due to the students' lack of familiarity with the syntactic rules of Logo, something which often led to their disappointment and their urge to quit. The following mistakes were observed on a regular basis: the students left no space between the operators, in the procedure name they left a space between two words (e.g. movement 1 instead of movement1), they used the letter “o” instead of 0 (zero), they omitted semicolons before the variable, or forgot to put the word end at the end of the procedure definition. The Logo programming syntax could be a significant barrier for some students. It's easy to get caught up in the details of the programming syntax and lose sight of the big picture. Furthermore, it is a really frustrating endeavor for someone who had never had the interest or inclination to learn programming. By employing different programming paradigms, such as Scratch, the users do not have to write a complicated code. Instead, they can drag and “snap together” colourful graphical building blocks, each of which represents a simple programming instruction. By snapping together different combinations of these blocks, children can create sequences that build up into simulations.

As the students of both classes proceed to the sequence of activities, in order to gain time while keyboarding the appropriate code, we recommend students to copy-paste the code of the initial procedures from and to the Procedures Tab, so that they can later modify/expand it appropriately and move on to the next step. In each phase the initial code is expanded by adding to it a new command or a small sequence of commands in order to scaffold the familiarization with gradually increasing complexity. In the 2nd class, the preconstructed microworld had a positive effect, especially for the students who had not at all experience in programming. We consider that the preconstructed microworld functioned as a good starting point, as a solid ground for various alternative explorations, modifications and extensions, as a vehicle for collaboration and negotiation which promoted a better performance.

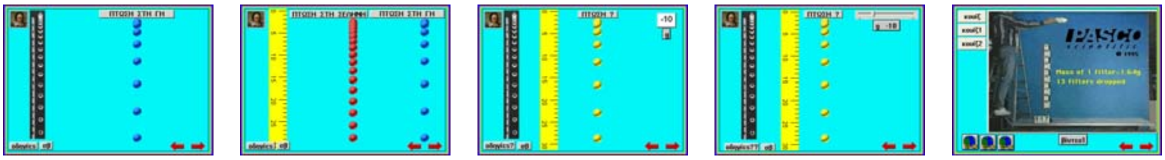
Table 1: Skills development per team.

Skills	# Team 1st Class									# Team 2nd Class										
	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	10	11
Code modification	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Use of new commands		√		√				√	√	√	√	√	√	√	√	√	√	√	√	√
New procedures development	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√
New simulations development		√		√	√			√	√	√	√	√	√	√	√	√	√	√	√	√
New objects import		√			√			√	√		√	√		√	√		√	√	√	√
Multimedia application creation		√		√		√		√	√		√	√	√	√	√		√	√	√	√
Webpages creation		√		√		√		√	√		√	√	√		√		√	√	√	√

In summary, as it is evident from the checkpoints in the matrix (see Table 1), comparatively to the 1st class, the 2nd class accomplished a better final result regarding the observed skills development per team.

In the phase where they were asked to create a variety of simulations, the students demonstrated their inventiveness; they built alternative personal models with different levels of detail and variations of methods. Following the teacher’s suggestion, some groups looked for relevant material on the Internet and in the installation folders of the softwares available (like Modellus: another computer tool for modeling and experimentation), in order to enrich their pages with images, videos etc. Three groups went on further to create simulations of different phenomena such as uniform translatory motion and symmetrical oscillation.

In Figure 2, we present indicative snapshots of the microworld corresponding to the evolutionary stages of a students' project work (Team 3 of 2nd Class), as resulted from the preconstructed microworld modification. We notice multiple pages enriched with additional material. In Figure 2a, the students defined a new procedure as "Fall_on_earth", renamed the corresponding button properly and added images (like an image of Galileo, a photograph of a free fall stroboscopic representation). In Figure 2b, we can see a parallel stroboscopic representation of the free fall on the earth and the moon (by clicking buttons "Fall_on_earth", "Fall_on_moon") that correspond to appropriate defined procedures, and also a ruler-shaped turtle used to measure the distance between the ball's stamps. In Figure 2c & 2d, the students proceeded to the parameterization procedure. They suitably defined the parametric procedure as "Fall_?" and then used a text box (Figure 2d) and a slider (Figure 2e) to input the value of variable g (where g: acceleration of gravity). In Figure 2e, the students added a video-experiment relating to the investigation of the free fall phenomenon (found in the installation folder of Modellus), hyperlinks to websites where relevant educational material can be found, as well as new buttons linked with procedures dealing with quizzes.



a *b* *c* *d* *e*

Figure 2. Snapshots of the students' project work microworld (Team 3 of 2nd Class).

In Figure 3, we see snapshots of the microworld created by another team (Team 8 of 2nd Class). In Figure 3a we notice the introductory page enriched with images and an announcement emerging in the presentation mode of the microworld, with the message "Let's investigate the Free Fall". In Figure 3b, we see the turtle shaped as an apple, two different text boxes as tables to output the values of time (t) and velocity (v) as opposed to the single table used in the preconstructed microworld. In Figure 3c, the students gave the microworld a game dimension. As we see, an emerging announcement is calling us to observe the movement and calculate the value of g, combining the values of time (t) and velocity (v) from the text boxes. In Figure 3d & 3e, the students used a parametric procedure and a text box to input the value of variable g (acceleration of gravity). In Figure 3e, we can see three text boxes as tables to output the values of time (t), position (y) (: ordinate Y) and velocity (v).

a *b* *c* *d* *e*

Figure 3. Snapshots of the students' project work microworld (Team 8 of 2nd Class).

Follow-up interviews of students revealed that the experience of both instructional methods led to a reduction of the anxiety towards programming, to a greater willingness to view programming as relevant to everyday life and to an increased willingness to approach programming challenges with a more positive attitude. The analysis of student answers on the worksheets revealed that: (a) students made significant gains in their ability to answer test items covering initial conditions, condition value and program flow; (b) students in all ability levels made gains in programming and modeling skills.

Among the special features of MicroWorlds Pro that contribute to the creation of an effective learning environment we should mention the following: The options Duplicate Page and New Page from the Pages Menu of the environment have proved to be particularly functional. In each new phase of the project, we encourage students to reproduce a selected page or/and add a new page in their microworld, in order to be able to trace back the sequential stages of their work, reflect upon them and reconsider their choices, as well as reuse the elements of the selected page and proceed to the necessary changes. In addition, the option Presentation Mode from the View Menu is functional to frame and demonstrate completed projects, as it centers the project on the screen and sets the area around the project to black, framing the presentation by hiding the Command Center, Tab, Toolbar, MicroWorlds Menus and Status Bar. The Project Tab displays the complete state of the project including all objects, whether they are hidden or not, as well as the state variables. This has proved to be especially useful for analyzing a project, finding unused objects on a page and/or proceeding to subsequent modifications.

Discussion

This pilot implementation in actual classroom circumstances and, as a matter of fact, in different classes on successive days, provided us with important feedback that led to modifications/interventions in the ergonomics, the appearance and function of the microworlds, as well as in the ameliorative reshaping of the worksheets and of the lesson plan. The preconstructed microworld functioned as a good starting point, as a solid ground for explorations-modifications-extensions, as a vehicle for collaboration and led to various alternative constructions of personal and social meaningful artifacts. The use of preconstructed microworlds for the creation of new artifacts with a gradually increasing degree of complexity encourages the systematization of knowledge and bridges the gap between the simple and the more complex. We need a further analysis in order to generalize the conclusions concerning the features of an effective instructional approach, in the level of planning, development and implementation, which responds to the special characteristics of the students of the particular class and of different classes as well. More research is needed for the identification of the computer-based programming environments special design characteristics that promote engagement, "thinking about thinking", construction, meaning negotiation and collaboration. Our future research plans focus on exploring the use of different modeling paradigms, such as Scratch and Modellus, by implementing alternate instructional strategies which might lead to the most effective combinations to support student engagement in simulation development.

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Generative Conversations in Game-based Learning

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Abstract: This study examines a secondary level game-based learning curriculum centered on a multi-player 3D game, in which students collaboratively make sense of phenomena related to the behavior of charged particles in electric and magnetic fields. We study the interaction among the students while they enlist resources in the form of the game and curriculum materials that serve as scaffolds for sense-making. Through the consideration of coordination of the perception-conception of resources with actions related to scientific inquiry processes, potential sites for generative conversations were identified. We suggest future directions for the design and study of game-based learning curriculum to foster generative conversations that better shape students' sense-making trajectories.

Introduction

Inquiry has come to be the object of good science education and its use as a teaching and learning approach has been the focus of research and discussion on educational reform (Anderson, 2002). In addition, changes that have taken place over the past few decades in the conceptualization of science and learning necessitate the need to adopt pedagogical approaches that allow students to engage in dialogical discourse processes consistent with the view of science as a practice with social and epistemological dimensions (Grandy & Duschl, 2007).

In order for learners to gain a deeper understanding of a body of science knowledge and the practice of science, it is vital for them to be engaged in *doing science*, in the practices and methods related to science-in-the-making used by scientists instead of just focusing on *learning about science*, that is just learning the established results of science (Van Joolingen, de Jong, & Dimitrakopoulou, 2007). Lemke (1990) likens the practices and methods used by scientists to "talking science" or "doing science through the medium of language" (p. ix) which entails participating in a whole spectrum of activities ranging from observation to the formation of generalizations using language as a system of resources for meaning-making. Meaning-making has also been positioned as a dialogic process employing a scientific social language (Mortimer & Scott, 2003). For Suthers (2006), meaning-making, in particular intersubjective meaning-making, is evidenced when participants involved in a collaborative learning activity contribute to a "joint composition of interpretations" (p. 321) which entails examining the interactions among participants while they engage in the activity.

Technology has shaped much of the developments taking place in the design of learning environments and offers possibilities for the provision of rich contexts within which meaning-making may be situated. Online role-playing games have grown in popularity in recent years (Galarneau & Zibit, 2007) and educators, academics and researchers have discussed the potential offered by 3D game environments to foster deep learning (Gee, 2003; Squire & Jenkins, 2003). For example, 3D game environments can be designed to involve the learner as an active participant in situations that may not be accessible in a traditional classroom (Jones & Bronack, 2007). During game-play, the player is constantly involved in a cycle of questioning and the formation, testing and revision of hypotheses; processes that happen rapidly and frequently during the game and accompanied with immediate feedback (Van Eck, 2007). Hence, 3D game environments lend themselves naturally to the provision of dynamic contexts within which learners may test scientific conjectures. This is especially valuable in the domains that deal with abstract concepts and phenomena for which many learners face significant difficulties understanding (Squire, Barnett, Grant, & Higginbotham, 2004). 3D game environments can also immerse learners in simulated worlds within which they may explore and make sense of the scientific phenomena instantiated in such worlds, hence facilitating their active participation and situated understandings (Steinkuehler & Duncan, 2008).

Situated learning is concerned with how learners dynamically construct knowledge and how the process is shaped by the ways in which they conceive of their circumstances, interact with one another, and act as members of a community (Clancey, 1995). Compared to simulations, games allow learners to be immersed in an environment where they are able to interact with the game as a system instead of as a combination of unrelated events, hence fostering the development of an "embodied empathy for a complex system" arising from the player being simultaneously inside the game as an avatar interacting with the game-world as well as outside the system as the one controlling the avatar (Gee, 2005, p. 82). Helping learners to achieve an embodied understanding for scientific phenomena by way of being embedded in a dynamic game system where they learn through experience and active experimentation (Chee, 2007) is what the *Centauri Learning Program*, a Physics learning program sets out to achieve. It employs the use of a 3D game environment to engage secondary school students in inquiry practices related to the sense-making of scientific phenomena that are unfamiliar to them. These inquiry practices include the making of observations, testing of hypotheses, engaging in formulation of explanations based on evidence, and the communication and justification of explanations (Grandy & Duschl, 2007).

In order for abstract and oftentimes, invisible, phenomena to form the focus of a learner's inquiry within a 3D game environment, the phenomena first has to be rendered visible for observation and subsequent manipulation through some means of representations within the game. The sense-making process is not one that is straightforward, especially when an unfamiliar phenomenon is being presented to the learner, consistent with the science-in-the-making situations that scientists encounter. This is further complicated by the fact that what information a learner conceives as evidence in a hypothesis-testing process is influenced by what the learner perceives to be of significance in the information in the first place. How the learner perceives a representation is tightly coupled to the meaning the learner attaches to the representation; the *perception* of the representation (i.e. how the representation is viewed) and the *conception* of the representation (i.e. how the representation is understood) mutually affect one another simultaneously (Clancey, 1997). This "dynamic simultaneity in (the) coupling of perception and conception" (ibid, p. 213) implies that what an observer perceives depends on how the observer interacts with the things in the world and what is being attended to as an object of interest. Clancey (2005) demonstrated an example of this dynamic simultaneity in his study of the interaction between two students as they learnt about linear equations using a mathematics software and he examined how the "process of 'viewing as' and interpreting is inseparable in human experience, so seeing something as meaningful and conceiving what it means occur together and is only subsequently followed by a coherent linguistic statement by which the meaning is represented" (p. 114).

In addition to the tight coupling between perception and conception of information, one also needs to consider the coordination between the perception of information and action because what one sees and does arise simultaneously giving rise to a new coordination of perception and action that shape subsequent behavior (Clancey, 1995). In this paper, we examine interactions among students involved in the *Centauri Learning Program* as they collaboratively engage in scientific inquiry processes while enlisting resources in the learning environment (the game and the associated curriculum materials that act as scaffolds). In particular, we study how the coordination between their perception-conception of scenarios encountered and their actions shape their sense-making trajectories.

The Centauri Learning Program

The *Centauri Learning Program* consists of a game-based curriculum designed around the use of a multi-player 3D game entitled *Escape from Centauri 7* (EC7) to support the learning and application of Physics concepts and principles to make sense of particle dynamics in electric and magnetic fields. EC7 (see Figure 1) is modeled upon puzzle games where players solve puzzles of increasingly complex natures with each successive mission or level. Players take on the role of explorers who crash-land on a planet where they encounter alien technology, such as emitters that emit charged particles. Players need to direct the charged particles at a target – a generator that in turn powers the next emitter, and so on. The aim is to reach the final mission where they direct charged particles towards generators that power-up a giant coil-gun that will propel a distress signal into space to enable them to escape from the deserted planet.

Figure 1. Screenshots of the main navigation map showing the levels (left) and the interface (right).

In order to manipulate the motion of the particles, players need to position vehicles, which deploy fields, in the paths of the particles. Players need to decide on the type of field to use (whether uniform electric or uniform magnetic), the position of the vehicle with respect to the particles and the setting of controls that determine the strength and direction of the field. A mission is complete when players manage to guide the charged particles around obstacles to hit the final target in the mission. The game-play would be straightforward if not for the fact that players are not told which field is of which type; part of the challenge is to make sense of the nature of the unknown fields through experimentation. Players are not assumed to have any prior knowledge of the nature of the fields; instead they need to make use of their understanding of Newtonian Physics to deduce how the fields affect particle behavior in order to complete missions strategically and without sole reliance on trial-and-error methods.

The interaction of charged particles with electric and magnetic fields is not one which is directly perceived with one's senses in everyday experience; it is an abstract phenomenon due largely in part to the invisibility of fields. EC7 depicts a sci-fi world in which charged particles, fields and the effects of their interactions are made visible and can be viewed from different perspectives in a free-roaming camera mode. As such, it allows the learner to dynamically manipulate the trajectories of charged particles through the adjustment of field variables. In the process, learners actively make sense of how charged particles behave in electric and magnetic fields through self-directed meaning-making processes grounded in embodied cognition where knowledge is seen as a capacity for action rather than as an object that can be transmitted from teacher to learner (Chee, 2007).

Providing the game experience alone does not necessarily ensure that deep learning will take place. In fact, it was one of our concerns that learners might go through the game, successfully completing missions through trial-and-error but without understanding the Physics concepts and principles underlying the behavior of charged particles in fields. This underscores the importance of designing the game-based learning experience by providing guidance and scaffolds so that learners will have opportunities to partake in the "socially shared practices of science" related to questioning, data collection, description of observations, finding patterns in observations and data and the development of scientific reasoning (Enfield, Smith, & Grueber, 2007). With this in mind, a curriculum was designed around EC7 to enable students to make sense of phenomena that were unfamiliar to them through participation in scientific practices. The curriculum was targeted at students in the third year of their secondary school year (ages 14-15 years) and who had not been taught about the interactions of charged particles with uniform electric and magnetic fields. It focused on fostering practices related to theory building (e.g. finding patterns in observations, and the forming, testing and revision of hypotheses) where students make sense of phenomena that are new and unknown to them. To scaffold the sense-making process, activity cycles comprising *game-play*, *small-group discussions*, and *whole-class forums* were employed to orchestrate the game-based learning experience.

The activity cycles are based upon the conception by Rogoff (1997) that the development of learners entails their participation in sociocultural activities that involve personal, interpersonal as well as community processes. Students work in teams of three to complete game missions and make sense of the behavior of the charged particles in the fields during game-play. During *game-play*, they actively experiment with electric and magnetic fields to control the motion of the charged particles and in the process gain a first-hand embodied sense of how fields and particles interact. As they engage in *small-group discussions*, they articulate their thoughts in the process of negotiating meaning with fellow team-members before converging on generalizations which they then subject to further interrogation by other teams during *whole-class forums*.

The *Centauri Learning Program* comprises a total of four activity cycles. Each activity cycle starts with game-play where students play one or two levels of EC7. Students are provided with an Exploration Log (log) that scaffolds their sense-making of the phenomena through the provision of scenarios and discussion questions that serve to draw their attention to various aspects of the phenomena. Each log is designed to scaffold students' sense-making through a dialogic process employing a scientific social language that is characterized by description, explanation and generalization (Mortimer & Scott, 2003). Description entails the making of statements providing an account of the phenomena in terms of its constituents; such statements often form the basis for evidences that need to be cited in explanations. Explanation involves accounting for the phenomena by establishing relationships between the phenomena and concepts through the application of some form of model. Generalization involves the making of a description or explanation that expresses a "general property of scientific entities, matter or classes of phenomena" (Mortimer & Scott, 2003, p. 32).

The level design of EC7 is closely aligned with the focus for each activity cycle; new physical phenomena or different aspects of the same class of phenomena are introduced at various missions to perturb the students' conceptions. Table 1 summarizes the key focus of each activity cycle and illustrates how the elements in EC7 and the accompanying Exploration Log for each activity cycle are designed such that the sense-making taking place in one cycle may build on what had taken place in previous cycles. For example, during Cycles 1 and 2, students go through the process of investigating the effect of the uniform electric fields on positively charged particles. During Cycle 3, the students encounter a new type of particle that behaves differently from what they have already experienced in previous cycles. This scenario sets the context for the students as they examine the reasons underlying the difference in behavior.

Table 1: Key focus of each activity cycle

Activity Cycle	Key Focus
Cycle 1 with sense-making scaffolded by Exploration Log 1	Phenomena related to charged particles (represented as orange-colored particles) traveling parallel or anti-parallel to a uniform electric field – acceleration and deceleration of particles
Cycle 2 with sense-making scaffolded by Exploration Log 2	Phenomena related to charged particles (learners were informed through a clue in the log that the orange-colored particles are positively charged particles) traveling in a uniform electric field – formation of parabolic paths
Cycle 3 with sense-making scaffolded by Exploration Log 3	Phenomena related to positively and negatively charged particles (introduced at the mission played during this cycle and represented as blue-colored particles; learners were not informed that these are negatively charged particles) traveling in a uniform electric field
Cycle 4 with sense-making scaffolded by Exploration Log 4	Phenomena related to positive and negative particles traveling in a uniform magnetic field – formation of circular or helical paths, depending on the angle between a particle's initial velocity and field direction

The logs are positioned as journals with entries made by explorers on their observations, explanations, and generalizations (Mortimer & Scott, 2003) as they explore the interaction between the particles and the fields. Each activity cycle are anchored upon the log that provides one or more trigger scenarios accompanied by guiding questions to scaffold students' formulation and testing of hypotheses in order to make sense of the interaction between the charged particles and the fields. As an example, Figure 2 shows an excerpt from the log used in Activity Cycle 3.

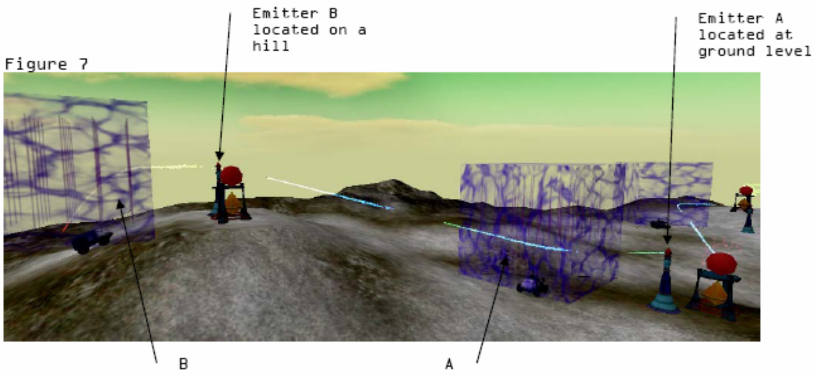
Exploration Log 3: Generalising patterns of behaviour

Log entry by (Team) Date

At every reconnaissance we conduct we uncover new phenomena or new aspects of the same phenomenon. We found ourselves modifying our hypotheses as we go along. For example, just when we thought we had figured out the behaviours of the particles, they start behaving in a way that goes against our expectations.

Scenario 3
Figure 7 shows a sky-cam shot of a situation encountered at Tergis. The behaviour of the particles in the regions labelled "A" and "B" is different even though the same type of field and similar field strengths are used. The field is directed downwards towards the ground in both regions. In this situation, particles from Emitter A travel towards the left to hit the generator powering Emitter B.

Figure 7



(a) How do I explain the difference in behaviour of the particles at "A" and "B"?

Figure 2. A scenario presented in the Exploration Log used during Activity Cycle 3.

Research

This study is a design-based research embodying conjectures (Sandoval, 2004) that a deeper understanding of Physics and of scientific inquiry practices may be fostered through a game-based learning approach where students jointly investigate and make sense of unfamiliar phenomena in a simulated world. We are interested in studying how the sense-making process unfolds as the students collaboratively study the phenomena while drawing upon material resources in the form of the game and the logs. At the time of writing, the research had gone through four iterations. In the following sections, we provide a brief overview of the participants involved in the third iteration of the design-based research, the method of data collection, and data analysis.

Participants

The *Centauri Learning Program* was implemented as a module comprising eight sessions with each session lasting 1 hr 30 min in an independent, all boys' school. The school set aside a period of three weeks during which the school time-table was suspended to allow their secondary three students (ages 14-15 years) to attend 12-hour modules covering a range of subjects and topics. A total of 36 students volunteered to participate in the *Centauri Learning Program* module. We worked with a Physics teacher, Mr. Teo (names used in this paper are pseudonyms) who had observed the conduct of the module with a different group of students at an earlier iteration. During the third iteration of the research, Mr. Teo facilitated the module as the main teacher with the first author supporting as co-teacher by providing just-in-time facilitation during small-group discussions among the students. Mr. Teo was provided with a facilitation guide comprising all lesson plans and curriculum materials. Regular discussions were held between Mr. Teo and the first author throughout the module. In addition, two LSL colleagues were present during a number of the sessions to record field notes and to conduct in-situ interviews.

Data Collection

During the sessions, students worked in groups of three which they formed on their own. Four student groups were video-recorded and the remaining eight groups were audio-recorded. Artifacts such as the students' completed logs, presentation charts used during whole-class forums, final products encapsulating their generalizations of the phenomena, and reflections individually penned by the students were collected. Pre- and post-intervention interviews and focus group discussions with the students were audio-recorded or video-recorded. Field notes were taken during the sessions and the discussions with Mr. Teo after each session were audio-recorded as well.

Pre- and post-tests were also administered. The instrument comprised of eight multiple-choice questions drawn and adapted from the Force Concept Inventory (Hestenes, Wells, & Swackhammar, 1992; Halloun, Hake, Mosca, & Hestenes, 2008), which was designed such that respondents need to make a choice between Newtonian concepts and commonsense beliefs or misconceptions. The Inventory probed for misconceptions as the distracters for each question were based on research findings about students' commonsense beliefs. A second tier was added to the multiple-choice questions by way of asking respondents to provide justifications for their choice. In addition, three short-answer questions were added such that the pre- and post-test would address the range of Physics concepts and principles fundamental to the content of the *Centauri Learning Program*. Taken as a whole, the pre- and post-tests were designed to provide an indication of the students' understanding of the concepts related to Newtonian Physics and to the dynamics of charged particles in fields.

Data Analysis

The *Centauri Learning Program* adopts the situated view towards learning that emphasizes development of knowledge in the course of activity as learners participate in collaborative processes (Clancey, 1995). As Interaction Analysis views knowledge and practice as being "situated in the interactions among members of a particular community engaged with the material world" (Jordan & Henderson, 1995, p. 41), it lends itself well as a method for analysis of the video data collected in this study. Interaction Analysis, a video-based analysis, is characterized by the investigation of "human activities such as talk, nonverbal interaction, and the use of artifacts and technologies, identifying routine practices and problems with the resources for their solution" (ibid, p. 39). As part of the process to study the interactions among students as they played the game and participated in discussions, content logs were made while the video data were viewed. The content logs summarized events observed while viewing the video data collected for the four student groups being studied. Hence they served as an overview of the data collected as well as a record of group interactions that were later discussed in context of the research focus. The logs also record interesting segments or interactional "hot-spots" (ibid, p. 43) where more detailed transcriptions could be made for in-depth study. One interactional "hot-spot", signaled by an increase in discussion activity among students, was observed across all iterations and it coincided with the start of Activity Cycle 3 when students first encountered the negatively charged particles represented as blue-colored particles in the game. In the following section, we describe the analysis of the interactions that took place among a group of students as they attempted to coordinate their perception-conception and action (Clancey, 2005) in order to make sense of the situations encountered in the game and in the scenario presented in the accompanying Exploration Log. A paired *t*-test on the pre- and post-test scores was conducted to gauge the students' conceptual understanding of the behavior of charged particles in electric and magnetic fields.

Analysis of the Interactions

The paired *t*-test conducted on the pre- and post-test scores revealed a significant difference between the scores ($t(33)=11.9$, $p<0.00$) and suggested that there were learning gains on the whole with regard to students' understanding of the concepts involved. For a qualitative study of how the students made sense of unfamiliar phenomena, we examined the interactions among the students as they engaged in game-play and discussion.

During Activity Cycles 1 and 2, the students encountered positively charged particles during game-play and had already formed certain relations pertaining to the behavior of positively charged particles in the electric field. This formed the backdrop to the episode that took place at the beginning of Activity Cycle 3 when three students, Peter (P), James (J) and Billy (B) attempted to answer a question posed in a scenario in the log (see Figure 2) – why particles showed different behaviors while traveling in two regions (region A and region B) even though the fields in both the regions were the same type of field with the same direction and strength. Three excerpts containing discourse related to the question in the scenario will be presented. The first excerpt began at the point when P was studying the scenario in the log while waiting for the game mission to load.

P: If both are directed downwards, how come this one goes left? (P asks J, pointing at his own log.)
J: (J takes the log from P.) Huh? Both are directed downwards?
P: (Points to the log and reads from it.) "The field is directed downwards in both regions."
J: Same type of field?
P: (Points to a phrase on the log and reads it.) "Same type of field and similar field strengths".
J: (Pauses to read the log.)
P: (P tries to take his log back from J.) Never mind, I think we go to the game and see first.
J: (J pulls the log back from P.) No, this is not (J points to the log). I think from the top, it's just move up. This one . . . both directed downwards?
P: (Silently points to the specific phrase in the log to J.)
J: Huh? Then this is a different field (points to the diagram). Confirmed.
P: No, but they say it's the same field. (Looks at the log.) It's the same type of field of similar field strength and it's directed downwards in both regions.
J: (Gives a quizzical look.) Why so strange?
P: We need to play this.
J: (J starts to play the game; B leans closer over to look.) Hey? Blue trail. Oh, it's a blue one. Let's see what can my field do. (Adjusts controls for the field strength.) Hey, it travels opposite, you know. I push here (points to the screen and moves his finger to the left), it goes the other way (moves his finger to the right).
P: Travels the opposite direction?
J: (Adjusts controls for the field strength.) You see, it's traveling in the opposite direction.

Peter highlighted certain aspects he noticed in the log scenario to James by directly quoting the log (lines 04-05), to which James responded by way of a question on whether or not the fields in both regions were the same (line 06). Peter's response was to directly quote another sentence in the scenario (lines 07-08). He then suggested playing the game (lines 10-11) before discussing the scenario. However James insisted that the scenario showed different fields at work in the two regions (line 15). Peter corrected James and rephrased what was written in the log (lines 16-17). In lines 6-17, we see a trouble in talk or a "hitch in interaction" (Jordan & Henderson, 1995, p. 71) where James questioned Peter twice on whether the fields in the two regions were of the same type (lines 06 & 15) and Peter insisted both times that the fields were indeed of the same type (lines 07 & 16). Although a repair in the interaction was achieved through an implicit agreement to play the game (lines 19 & 20) before resuming discussion of the scenario, the disagreement with respect to whether or not the fields were of the same type still remained.

In this excerpt, we see Peter highlighting textual descriptions presented in the log – the particles were traveling in the same type of field with similar settings. In contrast, he did not highlight information that was visually presented in the scenario – the particles in region A curved upwards whereas those in region B curved downwards. In other words, what Peter fore-grounded was the textual description of the fields in the two regions and what seemed to comparatively remain in the background for Peter were the behavior of the particles in the two regions as represented in the diagram. In order to arrive at an answer to the question presented in the log scenario (why the particles behave differently in the two regions) one has to attend to and coordinate the evidences embedded in the text as well as in the diagram of the log.

Within the first minute of playing the mission, James noticed a new type of particle color-coded blue (line 20). He applied a field on the new particle to see how the particle would behave in it ("let's see what can my field do"; line 21) and commented that it "travels opposite" (line 22), without stating his basis for comparison. In using the indexical term "opposite", it was not clear whether James meant that the blue-colored particles traveled in a direction opposite to that of the *field* or to the direction of *motion of an orange-colored particle* immersed in the same field. Peter did not ask for clarification of what James meant by "opposite".

While Peter highlighted textual information provided in the log (lines 1-17), James highlighted observations he made in the game (lines 20-26). However, no attempt was made to relate the information in the game fore-grounded by James with the information in the log fore-grounded by Peter. In Clancey's terms (2005), to relate these two types of information involves a coordination of perception-conception of the information (e.g. seeing the information as being relevant to the answering of the question at hand and understanding the significance of the information) and action (e.g. comparing and contrasting the information, discussing the implications and drawing inferences). For example, if Peter and James had juxtaposed what the former observed in the log and what the latter observed in the game, the juxtaposition might have led them to a generative discussion that could move them closer to answering the question posed in the log scenario. However, as no apparent coordination occurred between the perception-conception of the information drawn from both the log and the game, and a discussion of what the information they attended to could mean and imply, the question of why the particles behaved differently remained unanswered.

The students went on to focus on completing the level mission for the ensuing 16 minutes, during which the talk focused on the positioning of the fields in order to guide the particles toward the intended targets. The second excerpt we examined occurred at the end of the 16 minutes when Peter again turned to James to ask about the log scenario.

P: (Stops playing the game and picks up his log.) Hey (nudges J), how do you explain the difference in particle behavior?
J: Because there are differences in particles. Simply because they are different particles.
P: Are you sure?
J: Or else, what? It's the same field, the only variable left is the particle.
P: (Remains quiet and wrote on his log: "The particles are different as the only variable left to adjust is the particle's properties. The different particles react differently to the field.")

Peter revisited the question in the log and asked James to explain the difference in the behavior of the particles. During the course of playing the game, James came to a conclusion that the difference in the behavior shown in the scenario was because the particles were different in some way. In coordinating his perception-conception of the behavior of the particles as observed in the game and his action in drawing an inference (line 32), James attributed the difference in particle behavior to the particles being "different" (line 29-30). However, it was not clear what property he was referring to which made the particles "different"; neither did Peter attempt to probe and elicit the property of the particles that made them "different". Instead, Peter posed a closed question (line 31) and James responded by briefly stating his reason underlying his conclusion – "the only variable left is the particle" (line 32). The excerpt ended in silence as Peter continued writing on his log. This indicated yet another missed opportunity for Peter and James to engage in joint reasoning to extend their discussion. A generative conversation could have been fostered by a coordination of the perception-conception of observations made in the game and log with some form of reflexivity whereby learners monitor their progress in the inquiry process. This might have involved the "monitoring of their speech and thought, interrelating alternative viewpoints, evaluating their own and others' performance and displaying an awareness of strategies" (Edwards & Westgate, 1994, p.154). The third excerpt we examined took place about a minute after the second excerpt when Mr. Teo stopped by the group to check on their progress.

T: So, what did you notice about the differences? One is orange, one is . . .
P: One is blue (claps his hands).
T: Other than that?
P: Not much.
T: Only color differences?
J: Reaction to the field.
T: What kind of reaction?
J: Different . . . bad reaction.
T: Bad reaction?
J: Yes.
T: What do you mean by "bad reaction"?

47 J: Because we do not know how to . . . (smiles sheepishly)
48 T: (Pauses, gives a slight smile and walks over to another the group.)

Mr. Teo started by asking them to share what differences the team had noticed regarding the color-coding of the particles (line 36). He followed his first question by prompting the students for other differences that they had noticed (lines 38 & 40). Peter and James did not follow-through with Mr. Teo's attempt to direct their attention to aspects other than the color-coding of the particles. On the contrary, hitches started to appear in the conversation (lines 43 & 45) and despite Mr. Teo's attempts to repair the conversation by asking James to clarify what he meant by "bad reaction" (lines 44 & 46), the students did not try to sustain the discussion. The group missed yet another opportunity for a generative conversation that might have helped them to resolve the question that puzzled them. This pointed to a need for the students to coordinate their perception-conception of observations made in the game and the log with the teacher's confirming, re-constructing, instructional, generative and re-orienting moves (Lidar, Lundqvist, & Ostman, 2006) meant to scaffold their sense-making.

One thing that stood out in all three excerpts was the silence of the third member in the team, Billy. Compared to Peter and James who often engaged in discussions and playful bickering, Billy had a quiet disposition and often played the game silently in comparison with Peter and James who often took turns to give commands on how the electric or magnetic fields should be positioned in order to manipulate the paths of the charged particles. Near the end of the session, Peter asked Billy to show him his log. It was only then that Peter learnt that the difference in the particle behaviors could be due to the difference in the polarity of the charges, as explained in Billy's written response:

> The particles have a different charge. Emitter A emits negatively-charged particles. Even though the field direction is downwards, the particle moves up. Emitter B emits positively-charged particles. These particles tend towards the same direction as the field's direction.

Billy's written response, when contrasted with Peter's (lines 33-35) and James' ("They are different particles") suggested that Billy went a step beyond the conclusion expressed by both Peter and James (that the particles are different in some unspecified way) to conclude that the difference in the behavior of the particles was due to the difference in the polarity of their charges (that one is positively charged whereas the other is negatively charged). Peter and James did not involve Billy in their discussions and neither did Billy volunteer his views and this possibly resulted in a missed opportunity for a generative conversation by the entire group.

Discussion

Clancey (1997) highlights the indexical nature of representations in that the way in which someone interprets a representation, by means of perceiving its form and conceiving its meaning, depends on the ongoing activity. He observed that in inquiry, the "partial understanding shapes the looking and manipulating process" and that "the constructive process is therefore neither top-down from concepts nor bottom-up from perceptions" (ibid, p. 213). This is consonant with the notion that sense-making constitutes and is constituted by a moment-to-moment unfolding of events that shape the trajectory of the sense-making process itself. The hitches in interaction observed in all three excerpts discussed in the preceding section suggest that there was a lack of coordination of perception-conception of information drawn from resources available in the game and the log and the actions associated with scientific inquiry processes (e.g. act of observing, explaining etc), leading to missed opportunities for generative conversations. We suggest that in a game-based learning curriculum focusing on sense-making through scientific inquiry processes, the sites of successful coordination between perception-conception and actions are also the potential sites for generative conversations (Figure 3). Table 2 summarizes examples of successful coordination that potentially lead to generative conversations.

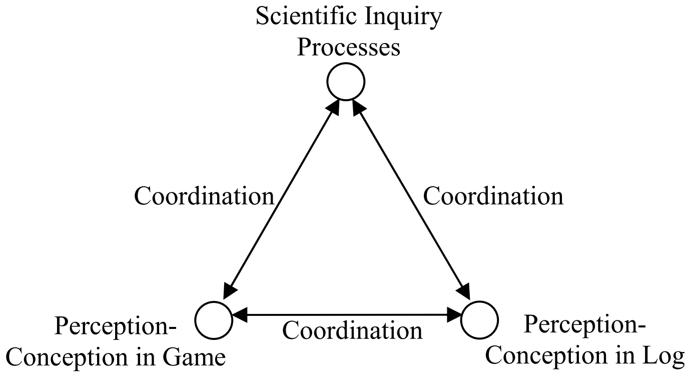


Figure 3. Sites of coordination of perception-conception with actions associated with scientific inquiry.

Table 2: Examples of successful coordination and potential sites for generative conversations

Coordination	Examples
Coordination between perception-conception of observations in the log scenario with actions associated with scientific inquiry processes	• Making observations of textual information as well as graphical information in the log scenario • Reflexive monitoring of the process undertaken by the group in drawing upon the resources available in the form of the log and in the form of discussions with peers and with the teacher
Coordination between perception-conception of observations in Game with actions associated with scientific inquiry processes	• Setting up scenarios (based on those shown in the log or new scenarios designed by students) in the game to investigate particle behavior or to resolve disagreements • Making observations of particle behavior in the game • Reflexive monitoring of the process undertaken by the group in drawing upon the resources available in the form of the game and in the form of discussions with peers and with the teacher
Coordination between perception-conception of observations in the log and perception-conception of observations in the game	• Forming connections between what is observed in the log scenario and what is observed in the game • Using the log as a record of observations made in the game, and explanations and generalizations of particle behavior in fields

The reason why the particles at regions A and B showed different behaviors even though they were in the same type of field with the same direction and field strength was due to the difference in the polarity of the particles. The process of arriving at such a conclusion is not a straightforward one. The missed opportunities for generative conversations which curtailed the group's sense-making trajectory suggest that the coordination of resources in the game and the log with the actions associated with the scientific inquiry processes should not be taken for granted.

Missed opportunities for generative conversations observed in this paper point to a possible area for future research – how developers of game-based learning curricula and teachers may better scaffold and facilitate discussions among students that are more reflexive in nature. This entails fostering skills that enable students to evaluate their own progress during the inquiry process with respect to cognitive (e.g. formulation of questions, use of evidence, reasoning), social (e.g. management of group processes) and epistemological (e.g. interrogation of science as a way of knowing) aspects (Grandy & Duschl, 2007). Much of the type of science inquiry learning which takes place in schools focus almost exclusively on the conceptual structures and cognitive processes involved in scientific reasoning and almost entirely ignore epistemic frameworks and social processes despite the general consensus that science "as a practice has social and epistemological dynamics that are critical to engaging in the discourse and dialogical strategies that are core of what it means to be doing scientific inquiry" (ibid, p. 155). This further underscores the need for fostering greater reflexivity among students during sense-making so that they gain an embodied understanding of the phenomena being studied and for developing scientific inquiry practices.

Conclusion

In this paper, we described the *Centauri Learning Program*, a game-based curriculum designed around the use of a multi-player 3D game *Escape from Centauri 7*. We examined the interactions among the students as they collaboratively engaged in scientific inquiry processes through game-based learning while enlisting the resources available in the form of the 3D game and the associated curriculum materials that act as scaffolds. We identified potential sites for generative conversations that shape their sense-making trajectories of unfamiliar phenomena by studying the students' coordination of perception-conception of information and their actions related to scientific inquiry processes. Future developments to the *Centauri Learning Program* may focus on the fostering of greater reflexivity among students as they participate in scientific inquiry.

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Designing the Game-based Environment to Facilitate Learners' Interaction in Performance-based Learning by Virtual Pets

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Abstract: Digital game-based learning attracts increasingly attention due to its positive influences on learning. Different games promote different aspects of learning. This paper attempts to propose a performance-based learning (PeBL) approach to create stage contexts in game-based learning environments. A My-Pet-and-Our-Stage system is developed according to this PeBL approach, and contains My-Pet and Our-Stage, which contains pet-nurturing mode and task learning mode, pet-performance mode and pet-performance mode, respectively. The learners in order to gain identity-making in front-stage, and therefore the learners need to be effort-making in back-stage. Since these the animal companions are driven by learner models.

Introduction

Digital game-based learning attracts increasingly attention due to its positive influences on learning (Ke, 2008; Kiili, 2005; Rosas et al, 2003). Digital games often own multiple motivational factors, and are helpful to motivate people to learn (Crawford, 1982). In other words, game-based learning is a potential way to provide learners with a great deal of learning opportunities to improve their learning. Therefore, Gee (2003) suggested that human's learning should adopt good learning principles built in the game design.

Besides, it is the natural for children to enjoy games. To children, a game is learning, acting, adapting, living, or working (Papert, 1994). Since, a child would choose a game based on their intrinsic motivation, they would naturally actively participate in playing the game. They would be naturally engaged. Therefore, the children playing game are full of laughter and they aren't tired of playing games. In the past, some researchers promote strangely that we could reach the education goal by game (Froebel, 1887; Papert, 1994). The children interactive with different game could improve the development of different aspects (Luckin, Connolly, Plowman, & Airey, 2003). Thus, we could provide a stage where the performers could easily perform themselves. Further, we could take the virtual learning space as a performance stage performance. In this stage, the learners could either play the role of performers, present their production and performance, or play the role of audiences, appreciate and comment the performers' work.

This study will propose that environment of pet-style as virtual character support the performance stage required by learning, called My-Pet and Our-Stage. The learners need to bring their trained animal companions, as virtual pets, and join the activities on the stage. The animal companions substituted the learners present what they learn on the performance stage and competition stage. It is performance-based learning approach that the process that the learners train the animal companions and make them show.

Table 1 Summarized the Related Projects

	NintenDogs	NeoPets	Triple-A Game Show
Since	2005	1999	2006
Description	Nintendogs features an animated puppy which owners must feed, water, walk, wash, groom, play with and train.	Neopets, a virtual pet website, has many active games from which users can earn Neopoints and awards.	The student teaches his or her agent and customizes the agent's look. The student and agent then participate in an on-line game show with other students and their agents.
Agent	Pet-like agent	Pet-like agent	Human-like agent
Game type	Pet-training game	Puzzle game	Agent-teaching game
Subject	Child	Child	Adult
Categories	Competition	Performance/Competition	Competition
Platform	Nintendo DS	Personal Computer	Personal Computer

Related Research and Projects

Pet-nurturing simulation games can be "simulations of real animals, as in the " Petz series" or "fantasy ones like the Tamagotchi "(Webster, 1998). Unlike biological simulations, the pet does not usually reproduce. They generally do not die. The pet is capable of learning to do a variety of tasks. "This quality of rich intelligence distinguishes artificial pets from other kinds of A-life, in which individuals have simple rules but the population as a whole develops emergent properties". For artificial pets, their behaviors are typically "preprogrammed and are not truly emergent". Pet-raising simulations often lack a victory condition or challenge, and can be classified as software toys. See Table 1 summarizes the related research, including NitenDogs (2008), NeoPets (Ito & Horst, 2006), and Triple-A Game Show (Schwartz et al, 2007).

Performance-based Learning Approach

Recently, through game-based learning makes children have different benefits (Guberman & Saxe, 2000; Luckin, Connolly, Plowman, & Airey, 2003; Squire, 2005). In this part, we describe the performance-based learning (PeBL) approach which facilitates the transition of educational virtual stage design that for intention in game-based learning. Before introducing the PeBL approach, educational roles of pet-style virtual character, as animal companions, in two dimensions are identified.

Two dimensions of intention: identity-making and effort-making

Previous studies pointed out that why we utilize technology to design virtual pets for learning located in that virtual characters bear quite promising opportunities to play essential roles to deepen both engagement and reflection (Chan, 2005). This paper proposes a performance-based learning (PeBL) approach, focusing on two aspects. First, the 'back-stage' denotes motivation of learners to engage in learning activities and encourage continuously efforts to accomplish assigned learning tasks, as training and learning. Second, the 'front-stage' implies that a learner is provided with feedbacks from different perspectives to promote reflection, as performance and competition.

According to the performance-based learning approach, educational roles played by animal companions in game-based learning could be categorized into two dimensions: effort-making and identity-making. For the effort-making dimension, personal companions are designed to motivate the learners to participate in a series of learning activities. For the identity-making dimension, personal animal companions are designed to help the learners observe, compare, and evaluate her learning outcome from different perspectives.

PeBL Approach

In order to facilitate the design of virtual characters in effort-making and identity-making dimensions, the PeBL approach is proposed. The PeBL approach consists of three elements: *learners*, *game world*, and *learner models*.

The game world is a digital game environment in which learners attend learning activities which are one kind of game playing. A learner's profile and the portfolios in the activity space are collected in the learner models, which may further enable the behavior of animal companions. In other words, learner models provide indicants for animal companions to play appropriate educational roles and govern their interactions to benefit learners' learning.

My-Pet and Our-Stage

My-Pet-and-Our-Stage (MPOS) is an animal companion system (Chen, Deng, Chou, & Chan, 2007), designed for children's learning companion, which are portrayed as pet characters called My-Pet. Children interact with My-Pet and keep pets engage them learning motivation, and participate in learning tasks and performance activities, which contains My-Pet system and Our-Stage system.

The learners need to complete pet-nurturing game and the learning task in back-stage, called My-Pet system; the learners have to dominate pet to performance and competition in front-stage, called Our-Stage system. In My-Pet system, the learner could control his/her My-Pet, a virtual character, and the My-Pet could present the learner's productions or performances. In Our-Stage system, the learner could control My-Pet to play the performer role and experience the hope and the response from the audiences (other learners).

Although the drama or sport performance means rival, it is effort making that is a positive effect on the performance development. To perform perfectly in the front-stage, the performers would prepare themselves ready in the back-stage. In the stage of preparation, in other words, the performers with the competition and pressure have turned into the motivators. At the same time, it would form the force and promote the performers self-regulation (Schunk, Zimmerman, 1998).

My-Pet

My-Pet consists of pet-nurturing mode and task learning mode. In My-Pet system, the activities were divided into two categories: pet-nurturing mode, home and training ground; task learning mode, school and forest types.

Pet-nurturing mode

In pet-nurturing mode, the learners need for their pet to nurture, that is nurturing game, which contains feeding, watering and treats, squirts at home and training ground, respectively. In the mode, if My-Pet's "hunger" attributes increases, then the learner needs to buy food to feed it. However, buying food requires virtual coins, which have to be earned according to the efforts made in learning activities in the learning task mode.

Some researchers pointed out that taking care of animal companions might be a powerful game strategy for learning (Chen, Deng, Chou & Chan, 2007). While learners interact with animal companions, they are actually taking good care of their own learning status in the form of game playing. In addition, pervious research adopts animal companions for learning with potential benefits. In regard to the motivation aspect, employing animal companion more than puzzle-based gaming for the learners to learn has sustainability (Liao, Chen & Chan, 2008).

Learning task mode

In learning task mode, the learners need for their pets to solve a series of problem, that is learning task, which contains learning to task and quests to retrieve items at school and forest, respectively. The learners should achieve the learning tasks and get the confidence from the learning. The learners with confidence would acquire from hardly completing the learning tasks by themselves rather than directly be given. The learners should constantly try to practice the learning task until them accomplishing it. In other words, the confidence is that the learners own the belief of successfully achieving the learning tasks. Besides, some studies found that feeding pets could potentially promote the learners the effort of behaviors (Chen, Liao, Chien, & Chan, 2008b).

Our-Stage

Out-Stage consists of pet-performance mode and pet-competition mode. In Our-Stage system, the activities were divided into two categories. First, pet-performance mode is the amphitheater and theater, Second, pet-competition mode is the stadium, arena, and competition type.

Pet-performance mode

In pet-performance mode, the pets substituted for the learners to join different kinds of activities, which contains pet-beauty contest, spotlights showcase at amphitheater and theater, respectively. Therefore, both the learners and the audiences have the opportunities to present their productions and performance on the stage. On the stage, the learners use My-Pet to show and to acquire the positive evaluation, applause, and encouragement from the audiences; under the stage, the audiences should appreciate and criticize the performances of the learners.

The audiences need to learn the advantage of performers, judge the disadvantage and then help improving their performance. Furthermore, the learners would play the performers roles and experience and expect the reflections from the audiences, other learners. The audiences could play the lurker, cheerer, encouragement roles as well and interact, communicate with the performers, other learners. In this kind of environment, every learner, including the peripheral audience and the core performer could find his/her performance style which fit himself/ herself. The learners would play the different roles and they could learn different knowledge from different aspects (Lave & Wenger, 1993; Wenger, 1998).

Pet-competition mode

In pet-competition mode, the learners need to adopt My-Pet and to race with other pets, which contains pet-challenge, pet race, and, catch Frisbee competition at stadium, arena, and competition, respectively. In mode, the learners could control and dominate own My-Pet, and My-Pet could present the learner's productions or performances. Therefore, the ability of the learners presents through revealing the skills and the appearance of My-Pet without directly showing out.

There is the advantage that the learners would be able to use My-Pet to reduce the pressure from the performance and My-Pet would be a buffer so the learner wouldn't directly face too much pressure (Lebow, 1993). In addition, some researchers suggested the concept of learning by substitutive competition, the employ of animal companion (My-Pet), as a layer of protection, in the process of competition to diminish the unfavorable effects (Chen, Liao & Chan, 2008a; Schwartz et al, 2007).

In My-Pet system, the learners have to complete the learning task and pet-nurturing game, with the need for keeping and feeding their My-Pet. In Our-Stage system, the learners need to train their pets in the stage performances and competition will be learned through a My-Pet to look at students and teachers. The learners would nurture and learn by My-Pet in the back-stage; the learners would dominate and control My-Pet in the front-stage. This process is not only effort-making in back-stage, but also identity-making in front-stage, called performance-based learning approach.

Future Directions

The objective of this study focus on the pet-stage effect in terms of two aspects: cognitive aspect (effectiveness, time-on-task) and affective aspect (self-efficacy, motivation). If the learners practice conceptual and procedure knowledge upon a certain level, and then they will show the productive results to other peers and teachers.

Through the system, learners could acquire the skills of planning and controlling their own learning progress, yet, they could own the confidence in the process of practice.

At present, the MPOS system is focused on the mathematics domain, and is still developing in progress. More feedback and comments from experiments are required for system improvement. A preliminary experiment is now planning to be conducted for elementary school pupils. Data gathering for this research consist of three parts: (1) scale and questionnaires, (2) discourse analysis of transcripts, (3) observation and interview.

Some researchers reported that using video game as an educational tool tend to be more positive (e.g., self-regulation of students' learning process, attention, and concentration) than negative (Ke, 2008; Kiili, 2005; Rosas et al, 2003). Therefore, the first investigative issue is that MPOS's impact on learners' self-efficacy, learners' motivation, learners' effectiveness, and time on task. Moreover, a number of studies should be further conducted in the future, including a formal experiment to examine the influence of learner's confidence, more scaffolding designs to support learners' learning in My-Pet-and-Our-Stage.

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Why be a Wikipedian

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Abstract: Wikipedia is a user-edited encyclopedia. Unpaid users contribute articles, edit them, and have heated debates about what information should be included or excluded. This study is designed to learn more about why people are willing to do this work without any fiscal compensation. Wikipedia administrators (*n*=115) completed an online survey with Likert-scaled items of potential types of satisfaction derived from participation as well as comments that were used to check the validity of the Likert-scaled items and allow participants to say in their own words why they were Wikipedian. Results showed that contributors in Wikipedia are driven largely by motivations to learn and create.

Introduction

One helpful way for understanding learning is to study how communities affect the learning process. For example, apprenticeships function as communities of practice (Wenger, 1998). In these communities, new members function as legitimate peripheral participants, at first taking on simple, but still essential, roles until they can become full-fledged participants in the activity, trade, or hobby. In classrooms, where learners are not expected to take on the role of teacher, and teachers themselves are typically not practitioners of their own subject (e.g., high school science teachers are usually not themselves scientists), a community of learners model can be used to guide and understand learning. In the community of learner model, students are assigned particular roles that they fill for a particular project or activity, but these roles are typically not determined by ones expertise in the subject or position in the learning community. This paper suggests that some web-based communities may function as a new type of community, a community of altruists. Working on Wikipedia has been documented to partly driven by the desire to be a member of a community (Forte & Bruckman, 2006), but some key differences exist between the well-studied communities of practice and communities of learners. Central to each of these communities are three elements: (1) the domain of knowledge, (2) the community itself, which creates relationships among members, and (3) the practice which creates a set of tools shared by the members (Wenger, McDermott, & Snyder, 2002).

Wikipedia is an interesting phenomenon, which has important implications for teaching and learning (Bruckman, 2002). It allows unpaid volunteers to edit and create entries without restriction and little barrier to participation and has resulted in a 2.5 million-entry encyclopedia that rivals *Encyclopedia Britannica* (Giles, 2005). One might be concerned that a document always in a state of change would often be wrong as a result of an editor was ignorant, careless, or malicious, but Halavais (2004) introduced thirteen “provably incorrect” errors into *Wikipedia* entries and found that all of these errors were removed within about two hours.

Research on how people contribute to *Wikipedia* indicates that regular contributors have a strong sense of community. Using how long characters in an edit remained in subsequent versions of an entry as a measure of quality, Anthony, Smith, and Williamson (2005) used statistical methods to show that as the number of edits for a contributor increased, the quality of their submissions rose for those contributors who worked under a pseudonym. For those working anonymously, the quality of edits dropped as the number of edits rose. The explanation for this phenomenon is that those who are using Wikipedia as an information source sometimes notice and fix small errors are “Good Samaritans”. Those who make large scale changes anonymously are much more likely to be vandals.

Bryant, Forte, and Bruckman (2005) interviewed nine regular contributors and found further evidence supporting that explanation. Wikipedians reported that as they started contributing more and more, members of the Wikipedia community would encourage anonymous contributors to register for an account and make attributable contributions. This work showed that Wikipedia shares characteristics of a community of practice (Lave & Wenger, 1991): (1) members are mutually engaged, (2) they actively negotiate nature of the enterprise, and (3) they build a repertoire of shared, negotiable resources. They also found differences between how novices and experts worked. Novice contributors edit what they know and gather information, often starting to contribute when they notice pages about things they knew about were missing something. Novices see themselves primarily as consumers and are reluctant to make drastic changes. For experts, “Wikipedians”, the whole of Wikipedia becomes more important than a particular set of articles. Further, Wikipedians become interested in improving not only Wikipedia, but also the community itself. This study also found evidence of mentorship consistent with CoP; some participants reported that they had been encouraged to edit under a pseudonym rather than contribute anonymously. One expert reported “We have a policy of don’t bite the newcomers and forgive and forget.” Some appreciated getting recognized, respect and recognition for their contributions. Rather than being defensive about their words being removed or changed, Wikipedians in this study were grateful to find that someone cared enough about their page to make corrections to it.

Though we agree with Bryant et al. (2005) with these similarities to communities of practice, we suggest that some of their findings point to a new kind of community. For example, many Wikipedians perceive their work as contributing to a greater good, and often cite the appeal of community (rather than the pages they maintain) as a key motivator for their participation. These seem different from communities of practice in which learning a particular skill or trade is the key motivator and participating in the community is a means to that goal. Also, the way that the experts interact with novices suggests that it is the experts who are invested in novices becoming experts rather than novices entering the community with an explicit goal of becoming expert. To the contrary, Bryant et al. (2005) suggests that people become Wikipedians almost by mistake.

Purpose and Rationale

The main objective of this study is to investigate the incentives of adults for contributing to Wikipedia– investing their time and effort for free. The motivations for contribution to Wikipedians are not fully understood and may provide new insights on motivations to participate in learning communities in and out of classrooms.

Theories of Motivation

We drew from five motivational theories to inform the design of our survey. Though none of these theories directly addresses why people might contribute to a volunteer project like Wikipedia, they served as a foundation for guiding the development of the survey.

Motivation to Learn

Dewey (1915) argued that humans possess an innate desire to learn. Wikipedia provides two kinds of learning, learning about the content of Wikipedia's 2.5 million pages, and learning about Wikipedia's features for managing the content.

Motivation to Create

Harel and Papert (1991) suggest that people learn better when they construct a public artifact. Constructionism, or "learning by making," helps people to acquire skills through personal creation and innovation. In the case of Wikipedia, contributors create new pages and participate with new ideas for improving the website. Project-and design-based pedagogies are similarly based on the assumption that providing opportunities for individuals, or groups of individuals, to create artifacts and evidence of their learning for others (Kolodner, Crismond, Fasse, Gray, & Holbrook, 2003).

Social Motivators

One of the intrinsic motivation factors acknowledged by Lindenberg (2001) is the obligation to the community. He proposed that people socialize when they work and interact consistently within the norms of a group. Also, the third level of Maslow's (1987) hierarchy of needs is belongingness and the need to be part of a group. Belongingness is also part of other educational motivation theories (e.g., Weiner, 1990; Ames, 1992; Ryan and Deci, 2000).

Extrinsic Motivators

Lerner and Tirole (2000) identified two types of payoff for contributions, an immediate payoff (e.g., ability to use the product) and a delayed payoff (e.g., potential future rewards in terms of recognition and reputation). Another extrinsic motivator that we considered is Murray's (1938) notion of dominance. He posited that individuals like to command, lead, and act as an exemplar for others. The dominative attitude is shown by the need to convince others of the "rightness" of one's opinion, to influence, to persuade, and to organize the behavior of a group.

Flow

Csikszentmihalyi (1975) who pioneered the study of enjoyment-based motivation suggested a state of "flow" where enjoyment is maximized. His work was based on experience sampling in which people were surveyed periodically, typically about seven times per day. He was interested in the activities that people were doing and their level of engagement (Csikszentmihalyi & LeFevre, 1989). He found that flow is attained when challenge and ability are balanced and increases as the level of challenge and ability rise. Other factors contributing to flow include clear goals and feedback, loosing track of time, and a feeling of personal control. Flow is also characterized by intense focus and concentration, an integration of action and awareness, and the satisfaction of the activity itself (Nakamura & Csikszentmihalyi, 2003).

Method

Participants

Wikipedia administrators were targeted because this was a convenient way to target Wikipedia contributors who were devoted, as opposed to casual contributors to the project. Wikipedia administrators have access to special features that help with maintenance such as deleting pages and blocking other editors. To become an administrator, a user is typically nominated for the role by another user (self nominations are permitted). If, after a week-long discussion period, a consensus of administrators approves, the user is nominated an administrator. As of October 2007 when the study began, the Wikipedia administrators' page listed 1372 members and 300 potential participants were randomly selected.

Materials

We constructed a 40-question survey based on the questionnaires employed in other motivational studies of open source projects and hobbyists (Hars & Ou, 2002; Pfaffman & Schwartz, 2003; Wu, Gerlach, & Young, 2007). Questions categories included demographic characteristics, the degree of commitment to the project, motivational factors, and comments to check validity of the items while providing further insight into participants' motivations. Participants were asked to rate the 30 Likert-scaled items on a scale of 7 (1 being unimportant and 7 being very important).

Procedure

We created a Wikipedia account for this project and, using that account, posted requests for participation on the "talk pages" of 300 administrators in our random sample. The call for participation was posted to the users' talk pages the first week of December, 2007. By the first week of January 2008, 21% of the potential participants had responded. The first week of February 2008, we again posted the call for participation to all 300 members of the sample (because the survey was anonymous we could not know who had responded already). By March 2008, we had 115 respondents (38% response rate). Because we knew only the pseudonyms of the administrators in our sample we have no indicators of how the demographics of those who responded may different from the whole sample.

Analysis and Results

Demographic data are reported in Table 1. The respondents were mostly (88%) male, half of whom were 18-29 years old; most of the rest were 30-49. Only 55% of the respondents reported being employed full-time. The majority of respondents (66%) reported that being a Wikipedian is "rewarding" or "very rewarding." This is not surprising since we expected administrators to be devoted to this unpaid work. Respondents are also long-term participants in this community with 73% of respondents reporting being involved for more than three years.

These wikipedians, though, don't spend much time completing wiki-related tasks such as participating in discussion or searching in the wiki. Apparently, finding the needed information to include in the website as well as editing the WebPages require much more time from the administrators. Proofreading the articles to obtain a better quality with more accuracy could be sometimes a complicated task. Also, a great part of the participants declared that they spend time searching the online libraries, newspapers, periodicals, journals, encyclopedias, and books in order to obtain information for addition or improvement of the Wikipedia website.

Measures

The survey included 30 questions related to the potential motivational factors for the administrators in Wikipedia. These questions are presented in Table 2. Descriptive statistics were calculated to obtain the measures of central tendency as well as the measures of variability of each of the identified items. Cronbach's alpha indicated 0.907 by determining how all items on test relate to all other test items and to the total test.

Though the potential motivators were grouped *a priori* according the motivational theories that informed them, we did not expect it to be the case that all items based on a particular motivational theory would have equal importance to respondents. To see which items seemed to be connected, an exploratory Factor Analysis (FA) was employed in order to determine which of the thirty items formed related subsets. FA combines into factors variables that are correlated with one another but largely independent of other subsets of items (Tabachnick & Fidell, 2007; Kim & Mueller, 1978; Rummel, 1970; Thurstone, 1947). This method was used as an expedient way to identify a smaller number of constructs (subsets) that represent the Likert-type items.

The first step to form the potential factors was performed by applying FA with principal components extraction, eigenvalues greater than 1.00, and choosing the absolute value to be more than .40 (Field, 2005; Ho, 2006). An orthogonal varimax rotation was used to maximize the variance of loadings for each factor – within factors, across variables – so that all the factors are uncorrelated with each other (Tabachnick & Fidell, 2007).

Therefore, varimax rotation tries to load a small number of variables highly onto each factor resulting in more interpretable clusters of factors.

Table 1: Participants' demographics and their activity in Wikipedia

		Frequency	Percent
Gender	Male	101	87.8
	Female	14	12.2
Age	18-29	57	49.6
	30-49	46	40.0
	50-64	8	7.0
	64+	4	3.5
Occupation	Full time student	38	33.0
	Full time job	64	55.7
	Part time student/job	13	11.3
Education level	High school diploma	11	9.6
	Some college	34	29.6
	Bachelors	34	29.6
	Masters	18	15.7
	Ph. D/J.D/M.D	18	15.7
Number of years of contribution to Wikpedia	1-2	31	27.0
	3-5	77	67.0
	6+	7	6.1
How rewarding the membership in Wikipedia is	I don't care	3	2.6
	Unrewarding	1	0.9
	Not very rewarding	4	3.5
	Sort of rewarding	31	27.0
	Rewarding	53	46.1
	Very rewarding	23	20.0
Hours/week spent on searching in Wikipedia	<1	30	26.1
	2-5	51	44.3
	5-10	25	21.7
	10-20	5	4.3
	>20	4	3.5
Hours/week spent on participating in discussion for Wikipedia	<1	31	27.0
	2-5	49	42.6
	5-10	23	20.0
	10-20	10	8.7
	>20	2	1.7
Hours/week spent on editing articles in Wikipedia	<1	15	13.0
	2-5	45	39.1
	5-10	32	27.8
	10-20	15	13.0
	>20	8	7.0
Hours/week spent on finding information to include	<1	36	31.3
	2-5	51	44.3
	5-10	21	18.3
	10-20	7	6.1

The FA yielded to eight factors with eigenvalues greater than 1.00. Kaiser-Meyer-Olkin (KMO) measure of sampling was equal to .825 which represents the ratio of the squared correlation between variables to the squared partial correlation between variables. This value close to 1 indicates that patterns of correlations are relatively compact and so FA should yield distinct and reliable factors (Kaiser, 1970; Field, 2005). Also, the Bartlett's test of sphericity which investigates the adequacy of the correlation matrix is significant (<.001). Therefore the hypothesis that the correlation matrix is an identity matrix – the variables are independent – is rejected. And therefore, the results of both KMO measure of sampling and Bartlett's test showed that using FA is appropriate for this study. However, since the main objective of FA is to reduce as much as possible the number of items, FA was re-applied to the 30 items to extract a fewer number of factors.

Table 2: The 30 likert-scaled items of potential types of motivation

Item#	Statement	Example	Mean	Deviation
1	Learning1: To read about my areas of interest	I enjoy reading Wikipedia pages to learn more about my favorite subjects.	5.5	1.5
2	Learning2: To know about dates, places, people, things	Wikipedia is full of information about different subjects from all over the world.	5.5	1.6
3	Learning3: To learn about tools	There are many tools used in Wikipedia where I can learn how to edit and delete pages and so on.	3.4	1.9
4	Learning4: To learn strategies and methods in Wikipedia	Wikipedia is one of the most popular wikis; editing the pages provides me with information about wikis strategies.	3.2	1.9
5 (Omitted)	Learning5: To know the little-known facts and stories around online communities	As a community member, it's interesting to know the rules in Wikipedia.	3.5	2.0
6	Learning6: For my personal growth	Being a Wikipedian adds different types of information to my knowledge	5.5	1.4
7 (Omitted)	Extrinsic1: To increase academic or professional success	Contributing to Wikipedia is helping me move forward in my education/job.	3.1	2.0
8 (Omitted)	Extrinsic2: To be better than others	Looking at the pages that I have edited adds to my confidence and self-esteem.	3.4	2.0
9	Extrinsic3: To enter competitions with others	Contributing to Wikipedia is a chance to compete with people about all kind of subjects.	2.0	1.5
10	Extrinsic4: To do something that few others know how to do	One thing I like in being a Wikipedia administrator is that few people are in such a position.	3.4	2.1
11	Extrinsic5: To gain social stature	Being an administrator in Wikipedia makes me more important and gives me respect from people who might not otherwise associate with me.	2.6	1.9
12 (Omitted)	Extrinsic6: I need this information in Wikipedia	I want to use this information in my studies/work.	3.3	1.9
13	Social1: To be liked	Being a Wikipedia administrator makes people like me.	2.5	1.7
14 (Omitted)	Social2: To share what I know	I am a Wikipedia administrator because it gives me a chance to share my knowledge with others.	4.7	2.0
15	Social3: To belong to a group	I joined Wikipedia, and participate on a list where people discuss types of wikis issues.	3.2	1.9
16	Social4: To help others appreciate or participate	As a Wikipedian, part of my mission is to show people that Wikipedia is as interesting and reliable as other encyclopedias.	4.7	1.7
17 (Omitted)	Social5: To use Wikipedia to stimulate conversation	When people learn that I am a Wikipedian, they are often interested in talking about it.	2.9	1.6
18	Social6: As a commitment to the Wikipedia community	Editing Wikipedia pages is one of my duties toward all the Wikipedians.	4.3	1.9
19	Creation1: To see fruits of labor	Seeing a page that I have fixed or updated is very satisfying.	5.7	1.2
20	Creation2: To adjust or personalize methods	I enjoy contributing to Wikipedia partially because I've created my own techniques for tracking and updating pages.	3.0	1.9
21	Creation3: To express myself	Being an administrator in Wikipedia gives me an opportunity to express myself by choosing what rules and strategies to add.	3.2	1.8
22	Creation4: To find or create something new or rare	I take great satisfaction in contributing new information or creating new pages that are succinct and correct.	5.7	1.5
23	Creation5: To nurture or sustain to completion or maturity	Once I edit a page, I work to see that the process is completed successfully by being sure that the rules are well fulfilled.	4.3	1.9
24	Creation6: To see my work/achievements	After editing pages, I like to go and check if someone changes or deletes my edits.	5.0	1.7
25 (Omitted)	Flow1: To feel time change	It's sometimes surprising to realize that I've spent 8 hours editing pages when it seemed like I just started.	3.1	2.1
26	Flow2: To feel a sense of control	Being an administrator gives me control over the processes and procedures of Wikipedia so that the pages I care about are of high quality.	3.5	1.9

Item#	Statement	Example	Mean	Deviation
27	Flow3: To overcome new challenges	No page is ever perfect or complete so as I learn more I can continue to correct and add to Wikipedia.	4.8	1.7
28 (Omitted)	Flow4: To do something as an end in itself	Though editing in Wikipedia obviously has an end, at least some parts of the process are fun in end of themselves. It's also great to just watch Wikipedians adding and editing pages.	4.9	1.7
29	Flow5: To have clear goals and feedback	When editing pages, I know what I want, and I know when I've to do it. When I look at the pages, I know whether it's good.	4.1	1.9
30	Flow6: For fun/enjoyment	I enjoy spending time editing Wikipedia pages.	5.7	1.2

The maximum likelihood extraction was used to find the factor solution which would best fit the observed correlations. This approach of extraction maximizes the correlations between the variables and the factors (Kim & Mueller, 1978; Harris, 1975). Finally, six factors were retained while ensuring the Chi-Square goodness of fit test between the model and the data (Harris, 1975; Kim & Mueller, 1978).

Items Removed from Factor Analysis

As a means to check the validity of questions, we first looked at their variance since high variability could be an indicator that respondents feel very differently about that item or it was misunderstood. Also, participants were provided with a comment box for each question as another approach for validity checking.

Item 25, with the highest variance 4.3 was “To feel time change” whose example was “It's sometimes surprising to realize that I've spent 8 hours editing pages when it seemed like I just started.” Several responses indicated that respondents understood and experienced this aspect of flow (e.g., “This also applies to the Internet in general, as well as video games,” and “[not lately, but] I used to edit almost all night.”) Further analysis of the comments suggested that, though people did indeed experience this loss of time in their work on Wikipedia, they were split on whether this was one of the things that contributed to their wanting to do this work. For example, one participant who rated this statement as [7], entered in the comment box “Definitely—I work a very dull office job and often kill time just reverting vandalism or fixing links;” another respondent who rated this item a [1] said “This is a result, not a motivating factor.” Several respondents who rated this item [1] or [2] mentioned “Not significantly” or “that hasn't happened to me.” We elected to omit this item because respondents' ratings might have different meanings. It is interesting to note that though losing track of time is one of the feelings associated with flow, for some, at least, it is an unpleasant side effect.

Similarly we omitted the next highest standard deviation item 14 with variance 4.2 because our example drew respondents’ attention to what it meant to be an administrator rather than whether the item contributed to their enjoyment of working on Wikipedia. “To share what I know” with the example “A big part of being a Wikipedia administrator is sharing my knowledge with others” caused respondents to focus on the meaning of being an administrator rather than whether sharing knowledge was why they liked to contribute to Wikipedia (rating [1]:“You can share knowledge without being an admin,” rating [6]: “That's important, but it has nothing [to] do with admin status”).

Item 8, “To be better than others” with the example “Looking at the pages that I have edited adds something to my confidence and self-esteem” with variance 4.0 was intended to be one of many reasons that being better than others might contribute to one's satisfaction, but upon looking at the comments, respondents were more likely to focus on confidence and self-esteem ([4]“adding to self-esteem is not the same as feeling better than others”) than ones that indicate that respondents do feel superior to others ([7] “My articles should be worthy of featured status;” [1] “I already know I'm great”).

Item 7, “To increase academic of professional success” with the example “Contributing to Wikipedia is helping me move forward in my studies or my job” with variance 3.9 was also omitted because it did not load on any factor, perhaps because it was bi-modal. Most comments were like “I doubt it will ever benefit my 'real-world' pursuits,” or “It's a hobby,” but some made claims to the contrary. Of particular interest to those interested in using Wikipedia in educational settings is this comment “I didn't think [working on Wikipedia] would [help me academically], but after getting to college I feel a lot more acquainted with the intellectual community than a lot of my peers do —it's like I had already been visiting this place for 2 years every day before this.”

Item 5, “To know the little-known facts and stories around online communities” with the example “In Wikipedia it is interesting to know the rules as a community member” with variance 3.9 proved to be confusing. Nearly half of those commenting said something like “I don’t understand this question or example,” and therefore, it was omitted too.

Item 12, “I need this information in Wikipedia” with the example “I want to use this information in my studies/work” with variance 3.6 did not load under any factor. Several respondents commented that the example did not make sense (e.g., “seems [like] reasoning” and “don’t understand the question”). The item was omitted.

Item 17, "To use Wikipedia to stimulate conversation" with the example "When people learn that I am a Wikipedian, they are often interested in talking about it" with variance 2.7 was also omitted because it did not load under any of the factors. Interestingly, many respondents included comments like "I try to avoid letting "real life" people know I'm Wikipedian…it just seems embarrassing."

Item 28, "To do something as and end in itself" with the example "Though editing in Wikipedia obviously has an end, at least some parts of the process are fun in end of themselves. It's also great to just watch Wikipedians adding and editing pages" with variance 2.9 did not load under any of the factors. The zero loading and mixed comments supported omitting this question from the factor analysis.

Having removed these items, a confirmatory FA was conducted using this reduced set of 22 items with the principal components extraction method for factors with eigenvalues greater than 1.00. The rotated varimax extraction of the 22 items yielded six factors accounting for 65.7% of the total variance (see Table 3). The sizes of the loadings reflect the extent of relationship between each variable and each factor. A statistical indication of the extent to which each item is correlated with each factor is given by the factor loading. In other words, the higher the factor loading, the more the particular item contributes to the given factor. For items that were loaded under two factors, only the higher loading was retained.

To check validity of the generated categories, we inspected comments on these questions. Factor 1, which accounted 28.8% of the variance, was labeled Dominance Motivation. Factor 2, which accounted 12.5% of the variance, was labeled Creation Motivation. Factor 3, which accounted 7.4% of the variance, was labeled Benefit Motivation. Factor 4, which accounted 6.2% of the variance, was labeled Learning Motivation. Factor 5, which accounted 5.6% of the variance, was labeled Social Motivation. Factor 6, which accounted 4.9% of the variance, was labeled Flow Motivation.

Once the factors were labeled with descriptive names, several of which were same as a priori groups, six new variables were computed based on the mean of the items falling under each factor. A one-way repeated measures ANOVA was conducted to detect the main effects between the located variables. The results revealed significant differences among the six factor scores, ($F(5, 570) = 118.81$, $p < .001$).

Figure 1 shows the Learning Motivation factor as the most powerful motive for the contribution to the Wikipedia with a mean of 5.47 on a scale of 7. The Creation Motivation factor is the second important aspect (5.08) over the Flow Motivation factor (4.89) and the Social Motivation factor (4.48). Finally, the Benefit Motivation and Dominance Motivation factors have the lowest importance with means equal to (3.21) and (2.88) respectively.

Discussion

These data suggest that Wikipedians are most motivated by their desire to learn. Since adults are able to identify their needs, they may engage in learning situations to meet a goal and to achieve competence because social competencies might affect their academic achievement (Knowles, 1980; Wlodkowski, 1989; Wentzel, 1994). Another indication of the desire to learn is that they rated reading highly. Another type of learning that could occur in the Wikipedia contribution is to *learn* new subjects involved in the process of participation which might affect their *personal growth*. For instance, the Wikipedia community has its own guidelines for contribution that encompasses a set of regulations. Some participants provided comments such as "excuse to learn new things all the time" and "adding to my own knowledge while updating content."

The second highest-rated factor is the creation of a public artifact. Constructionism or "learning by making" is shown to be a significant motivational factor that might help contributors acquiring skills through personal creation and innovation (Harel & Papert, 1991). Wikipedians develop and proofread pages for others to experience. Also, the act of *creation* itself might provide satisfaction through the process itself: from the initial stages to the completion of the project in order to witness the end of the course of action. Contributors to Wikipedia might be exercising their autonomy in the website design by *creating something new* and *overcoming new challenges*. The comments from participants show the importance of the creation factor through "creating new articles" and "seeing your changes appear immediately online."

The flow-driven motivation comes after the creation factor significance. Wikipedians considered *fun and enjoyment* with their Wikipedia-related activities. Hence, flow can arise when the challenge of the task matches the contributors' skills (Nakamura & Csikszentmihalyi, 2003). One of the participants reported "It's the best way I've found so far to kill time while I'm at work."

The social factor was next. Wikipedians seem to contribute as a *commitment to the community* since being a member of a community is one of the fundamental human needs (Maslow, 1987, Deci et al., 1991; Ryan & Deci, 2000). Therefore, social factors might affect motivation just as they affect learning. For instance, Anderson, Manoogian, and Reznick (1976) showed that children's motivation to work is to share their activity of drawing. Hence, members in the Wikipedia community could be interested in *helping others to appreciate* the contribution in order to expand the group or to share their knowledge. Some typical comments show the social motivational factor such as, "the realization that others share my obscure interests", "collaborating with others", and "interaction with the community."

Somewhat surprising is that the dominance as well as the benefit factors were not as important as the other incentives. Such findings indicate that having a social stature or possessing powerful qualifications inside the community is not the most significant objective for administrators. Obviously, some administrators might have strong benefit or dominance driven motivational factors. However, their percentage appears to be very modest compared with others within the sample.

Table 3: Rotated factor matrix with extraction method: principal component. Rotation method: varimax with Kaiser Normalization.

	Component					
Items	Dominance	Creation	Benefit	Learning	Social	Flow
Extrinsic5: To gain social stature	**0.780**					
Flow2: To feel a sense of control	**0.747**					
Social1: To be liked	**0.737**					
Extrinsic3: To enter competitions with others	0.627					
Extrinsic4: To do something that few others know how to do	0.613					
Creation3: To express myself	0.565					
Creation1: To see fruits of labor		**0.799**				
Creation4: To find or create something new or rare		**0.742**				
Creation6: To see my work/achievements		0.624				
Flow3: To overcome new challenges		0.589				
Creation5: To nurture or sustain to completion or maturity		0.530				
Learn4: To learn strategies and methods in Wikipedia			**0.714**			
Social3: To belong to a group			0.697			
Creation2: To adjust or personalize methods			0.668			
Learn3: To learn about tools			0.650			
Learn2: To know about dates, places, people, things				**0.847**		
Learn1: To read about my areas of interest				**0.817**		
Learn6: For my personal growth				0.660		
Social6: As a commitment to the Wikipedia community					**0.798**	
Social4: To help others appreciate or participate					**0.700**	
Flow6: For fun/enjoyment						**0.720**
Flow5: To have clear goals and feedback						0.589

Limitations

This study used Wikipedia administrators as a proxy for Wikipedia contributors who were invested in the activity. Because administrators have powers and responsibilities not available to all Wikipedia contributors, this group may not be representative of all contributors. A problem with any survey is that items may not be interpreted by respondents as intended by the instrument's creators. We used exploratory factor analysis to reduce the number of variables and to identify items that seemed confusing or not shared by most respondents. Analysis of the per-item comments showed that respondents' understanding of the various variables was consistent with our own and with each other.

Conclusion

Though space and time preclude thorough analysis and presentation of these data, also present in these comments were indications that Wikipedians function as a community of practice (consistent with the findings of Bryant et al., 2005). Initial analysis of these comments suggests that another strong motivator is an altruistic desire to create a resource for others to use. This suggests that perhaps Wikipedia, and perhaps other Web-based communities, may be driven partly by altruism. A framework for how these communities of altruists relate to communities of learners and communities of learners is presented in Table 4.

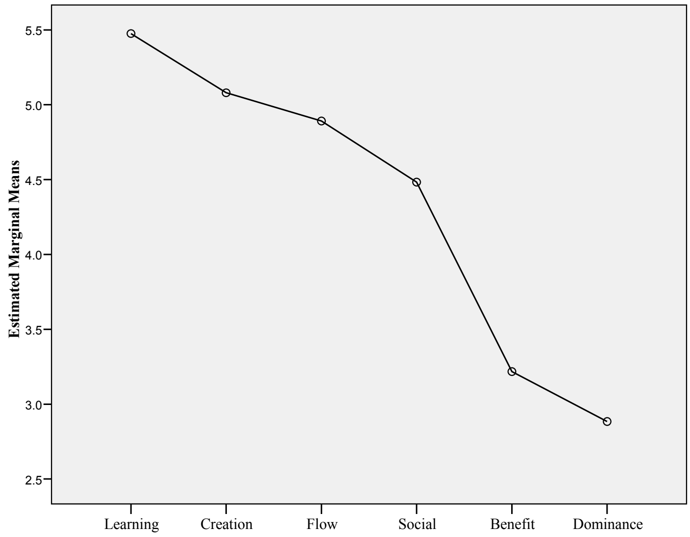

Figure 1. Estimated Marginal Means of Motivation on a scale of "7".

Table 4: Motivation for participation in different types of communities

Motivations for participation			
	Community of Practice	Community of Learners	Community of Altruists
Learning	Learn strategies/trades	Learn specific topics	Learn in order to share
Social	Become a full-fledged participant	Become a learner	Attract and develop more full-fledged participants
Flow	Balance challenge and skills	Sense of control uncommon in many classrooms	Enjoyment
Creation	Create artifacts for profit or beauty	Create projects	Create a shared resource for the common good
Extrinsic	Profit	Evaluation/Grades	None?

Further analysis of these data may provide some insight into this possibility, but further study and interview data are planned to investigate further this aspect of motivation in Wikipedians and Open Source Software developers. The study looked only at the English-language Wikipedia. Investigations of other-language wikipedias are in order to broaden see whether these findings hole across cultures. We were also surprised to find that only 12% of respondents were female. It is generally believed that the number of Internet users is now fairly balanced by gender (Horrigan, 2007), and there is little reason to believe that female Wikipedians would be significantly less likely to respond to our survey. Further research is needed to learn more about whether few women contribute to Wikipedia, or whether they are uninterested, or somehow excluded from becoming administrators. We are planning a further study to interview some wikipedians (perhaps by contacting contributors who are not administrators) to probe them for their hypotheses. We also plan to expand this research to Open Source Software developers to investigate their motivations to participate in those programming projects and whether those groups function as communities of practice as well.

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Knowledge Exchange as a Motivational Problem – Results of an Empirical Research Program

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Abstract: In many situations of computer-supported collaborative learning, it is a challenge to increase the willingness of those involved to share their knowledge with other group members. To study a prototype of such a situation of computer-supported information exchange, we arranged a shared database setting as a basis of an empirical research program. This knowledge-exchange situation represented a social dilemma: while contributing information to a shared database led to costs and provided no immediate benefit to the individual, the entire group suffered when all members decided to withhold information. A series of experiments identified a multitude of influencing factors in this situation: group size, awareness of the importance of information, costs of entering information, use-related bonus systems, feedback and recommendations, and group awareness. This paper describes the impact of these factors on people's willingness to share their knowledge with their cooperators, and concludes with a discussion of some practical consequences.

Introduction

The emergence of the "Web 2.0" and "Social Software" brought a great vision: that people will now have the opportunity to collect and combine their knowledge throughout the world, regardless of location, time, status or education. They can exchange opinions and experiences; they can discuss and start conversations with each other. Through Social Software, the knowledge of individuals will contribute to a comprehensive pool of knowledge, which is kept up-to-date by continuous participation of many users. Forces of "autopurification" will ensure continuing high quality. *Wikipedia – the Online Encyclopedia* made this vision real. Millions of users have contributed information to that encyclopedia. In a process of self-regulation, criteria of quality have been established: that information should be objective, complete and supported by references. And it is a fact that Wikipedia is now an established source of surprisingly valid information. What appears to be emerging here corresponds to the vision of "world knowledge". In terms of quantity, quality and up-to-dateness, Wikipedia sometimes even seems to be better than some traditional encyclopedias compiled by editorial boards (Giles, 2005).

But the Wikipedia project demonstrates, at the same time, the limitations of this vision of a general exchange of knowledge. Of all the hundreds of millions of users, only a very small proportion participate actively in the production of these encyclopedia texts. So Wikipedia also demonstrates a phenomenon that has been known for a long time from other contexts: people will gladly use information from a pool that was compiled jointly, but will not automatically and unconditionally make the pool greater by adding contributions of their own.

Those who have reported experiences from virtual seminars (Hesse & Giovis, 1997), news groups (Sproull & Faray, 1997) and information pools of organizational knowledge-management systems (Ardichvili, Page, & Wentling, 2003; Riss, Cress, Kimmerle, & Martin, 2007) came to similar conclusions. The majority of the users of these systems will just "lurk", i.e. read and use the content of whatever is available, but only contribute little or nothing of their own. The number of active participants and contributors is extremely small compared to passive users and recipients.

This paper describes this phenomenon from a psychological perspective. It explains the motivational situation of a user, shows how this leads to lurking, and it explains the consequences for the group. Based on such a theoretical view, the paper describes an experimental setting that allows investigating people's motivation to contribute to a shared knowledge pool. It describes a series of experiments which studied the effect of various influencing factors, both situational ones and tool-specific ones.

Knowledge Exchange as a Social Dilemma

News groups, wikis and information pools have many common characteristics, despite all their differences. As contributions from single users are made available to all users, information in such settings is a *"public good"*. The value of a piece of information is not diminished by the fact that it is being used by other users. This means that the public good will not be used up or consumed in the course of time (*"non-rivalry"*; Barry & Hardin, 1982). Its content is available to all users, regardless of whether or not they have provided any of their own information (*non-excludability*; Head, 1972). In this context, the decision to enter or not to enter information into a shared pool is a situation that has been referred to as a *social dilemma* (Dawes, 1980; also: Cabrera & Cabrera, 2002; Jian & Jeffres, 2006; Kalman, Monge, Fulk, & Heino, 2002; Kimmerle & Cress, 2007, 2008;

Markus & Connolly, 1990; Rafaeli & LaRose, 1993; Thorn & Connolly, 1987). A social dilemma is a conflict between interests of a group and those of individual group members. It describes a situation where a decision which is the best choice for each individual is no longer the best of all options if all members of the group take the same decision. Social dilemmas may be described in terms of a payoff structure, reflecting the cost and benefit of a decision which each group member and the group as a whole have to bear. So what is the cost and benefit if people are supposed to enter information into a shared pool of information?

First of all, potential providers of knowledge will have no immediate benefit from providing their own information, as they continue to have access to the pool of information regardless of whether or not they contribute any information themselves. Supplying information even leads to costs in terms of time that is needed for writing things down or losing an advantage that resulted from not having disclosed that information before. So balancing cost and benefit will lead a potential information supplier to the conclusion that it may be more efficient not to supply any information and only benefit from the contributions of others; or in other words: regardless of what the others do, not supplying any information leads to a higher reward than supplying information. The dilemma lies in the fact that this cost-benefit ratio will not work if we are looking at the group as a whole.

If no one in the group has supplied any information, the pool will remain empty and no one will benefit from the others' knowledge. So the payoff of the whole group is the lowest if all members completely withhold their own information. Such a social dilemma cannot be solved by an individual. On the one hand, withholding information is the most favorable choice from an individual's point of view (as long as providing information is linked with cost). But, on the other hand, withholding information, if this is the line followed by all, makes the situation worse for all than if they had provided information. In this sense, we describe a situation in which people can supply information to a knowledge pool as an "information exchange dilemma" (Cress & Kimmerle, 2008). In the terminology of social dilemma research, supplying or entering information may be described as "cooperation" and withholding information as "defection".

In a social dilemma, individuals receive the highest payoff if they "defect" while all other group members "cooperate". But this maximum reward cannot be paid out to everyone. If each individual follows the egoistic line, the information pool will be empty, and no one will be able to benefit from the information supplied by others.

Social psychology has introduced the terms *social loafing* (Karau & Williams, 1993; Shepperd, 1993) or *free riding* (Kerr, 1983; Marwell & Ames, 1979) for reaping benefits from contributions of others without contributing oneself. Research on cooperation in groups has identified some factors that might reduce such uncooperative behavior. A meta-analysis by Karau and Williams (1993) on loss of motivation in groups pointed out that individuals will tend to pursue *social loafing*,

- if their own individual performance cannot be assessed by others;
- if the assignment or task that has to be achieved by the group is perceived as irrelevant;
- if there is no standard for comparing group performance;
- if the group consists of unknown strangers;
- if individuals have the impression that their performance is redundant, compared to the achievement and contribution of other group members.

All this applies to characteristics features of knowledge communication through information pools, databases, wikis, discussion forums etc. Non-synchronous computer-mediated written communication is characterized by a great amount of time needed for writing down information, by high transaction costs, a high degree of anonymity, and – because social stimuli are reduced – by little normative influence on participants of that communication (Clark & Brennan, 1991; Reid, Malinek, Stott, & Evans, 1996). To make it worse, users of a database will normally not know each other and will only to some small extent be able to anticipate which specific information is required by other people for their tasks and ends.

So the question remains how a real exchange of information can be stimulated under such unfavorable conditions. In our laboratory we conducted various studies involving systematic variation of several features of the situation and its payoff structure and of the communication tools used. These studies were conducted in an experimental environment that represented the social dilemma character of knowledge exchange. The following paragraphs will first describe this environment and then the results of these studies.

Experimental Examination of the Knowledge-Exchange Dilemma

The Assignment

In order to create a situation in which knowledge exchange represents a social dilemma with a clearly defined payoff, the following scenario was devised and implemented. Participants in the experiments acted as staff of the salary accounting department of some fictitious company. They worked synchronously, but locally distributed in groups of six individuals. Payment was supposed to be on the basis of a piece rate, i.e. each person was paid for individual performance. The group received data on the sales performance of a large group of (fictitious) salespersons, in order to calculate the salaries that had to be paid to these people. The assignment was that each participant of the experiment had to calculate salaries for as many salespersons as possible, and the payment for participation in the experiment was based exclusively on the number of those calculated salaries.

A salesperson's salary in this experimental setting consisted of two components: a *basic salary* and a *premium* based on sales performance. During *Stage One* of the experiment, only basic salaries were calculated. This was a relatively simple calculation at the computer and took about 50 seconds to do. Each participant received 30 cent for each basic salary calculated. Each calculated basic salary could then be entered into a shared database, where it was available to other participants ("accounting staff") for the second stage of the experiment. Entering these data did, however, take some time during which no other basic salaries could be calculated. In other words, the more basic salaries a person entered into the database during the twelve minutes that Stage 1 lasted, the smaller was the time that was available for calculating more basic salaries, and the less this person could earn during Stage 1.

In *Stage Two* of the experiment, which lasted for nine minutes, the total salaries were calculated. Each participant received 25 cent for each total salary calculated. In order to calculate the total salary of a (fictitious) salesperson, this person's basic salary was needed. There were three ways of obtaining this information:

- The basic salary was available as the result of a previous calculation, if this particular participant had carried out that calculation during Stage 1.
- The basic salary could be retrieved from the database immediately (with no loss of time) if it had been calculated during Stage 1 by at least one other person and then entered into the database.
- If both was not true, the basic salary was not available in the system. In this case, the participant first had to calculate the basic salary (for no extra payment) in order to be able to calculate the total salary. This additional calculation required about 50 seconds each time.

The more basic salaries participants had to calculate during Stage 2, the more time they had to use up, which was then missing from their time for calculating total salaries. So in Stage 2, a participant earned the more money, the more other people had entered their calculations of basic salaries into the database during Stage 1.

The parameters for these experiments – i.e. the time that was available during Stage 1 and 2, the payment for calculating basic and total salaries – were calculated in such a way that a social dilemma was created that fulfilled the criteria as described above. Participants were (theoretically) able to earn (approximately) 23 Euros if they entered no information at all, but all other group members did. If this strategy had been pursued by all group members (by entering no information), each group member could have earned 18 Euros, which is less than if each group member had been cooperative and entered all calculated basic salaries. In this case each group member could have earned 20 Euros.

The Perceived Payoff Structure

In the experimental situation, participants were not explicitly informed of the payoff, but this was inherent in the assignment. After each successful salary calculation, an acoustic signal told them that they had just earned some more cents extra. During the entire experiment, the logo of a clock was on the screen, which was running backward and told participants how much time they still had. The awareness of a performance-related payment structure encouraged them to use their available time as effectively as possible, in order to calculate as many salaries as they could. The time that they had to wait for entering information into the database was perceived by them as time in which they effectively lost money.

In order to check if participants perceived this assignment as a social dilemma in the sense of the characteristics described above, they were asked – after having done the assignment – to estimate the following payoffs:

- Amount earned by a person who enters no information into the database, but whose five team mates enter each basic salary which they have calculated;
- Amount earned by a person if all group members (including that person) enter each basic salary which they have calculated;
- Amount earned by a person if all group members (including that person) enter no basic salary at all.

It became clear that participants were indeed aware of the social dilemma. Their estimates were that in the first case (social loafing in a group of cooperative people) someone might earn 26 Euros, in the second case (complete cooperation of all group members) 24 Euros and in the third case (complete defection of all group members) 16 Euros. These estimates show that the participants had realized that the situation contained a social dilemma. They had, however, over-estimated the extent to which they depended on other group members. They believed that they would benefit more from cooperation of the group members than was actually the case (cf. Cress, Kimmerle, & Hesse, 2006). Inter-dependence of the group members was perceived to be stronger than it really was. This will even intensify the social dilemma, because people believe that their cooperation or defection has a stronger influence on others than was really the case in this experimental assignment.

Results of a Series of Experiments

In a series of experiments, various factors were examined which might influence the readiness of people to supply information to a pool of data – even if the consequence is that they receive less than the highest possible payoff. We will first present those studies thast varied the characteristics of the situation, and then those studies that modified the communication tool.

Cooperation Behavior in the Course of Time

Various empirical studies on social dilemmas have shown that the extent of cooperation will decrease in the course of time. One factor which will increase people's motivation to cooperate is the expectation that their own behavior encourages other players to cooperate as well. This *reciprocity expectancy* (Komorita, Chan, & Parks, 1993) makes people more cooperative, especially in those cases in which the group is aware of some common future during which group members can reciprocate the cooperative behavior of their team mates. In situations in which people will no longer be able to interact with each other, this reciprocity expectancy is correspondingly low. Accordingly, the cooperation rate tends to drop at the end of a cooperation phase (Rapoport & Suleiman, 1993).

Our own studies have shown that this effect also occurs in the information-exchange dilemma situation. Figure 1 shows that at the beginning of the experiment, 60 per cent of all basic salaries that had been calculated were entered into the database, and at the end, this rate dropped to 40-50 per cent. This significant decline occurred regardless of the duration of the experiment. Regardless of whether Stage 1 lasted 12 or 36 minutes, the decline of cooperation rates did not differ.

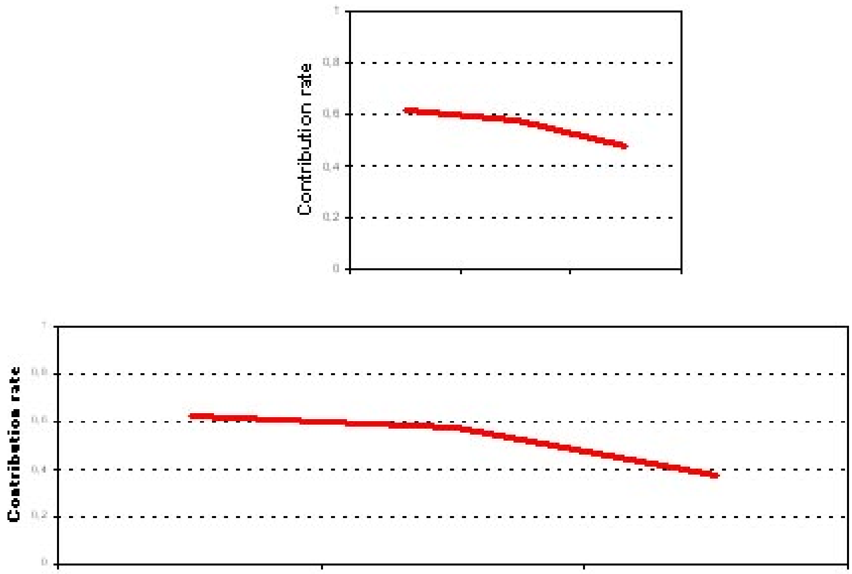

Figure 1. Contribution rate in the course of time. The upper diagram shows the rate of entering information in the condition where Stage 1 lasted for 12 minutes, the lower diagram in the condition that it lasted for 36 minutes.

Group Size

In many social dilemma situations, the size of the group influences the payoff an individual receives. This is the case if the public good produced by cooperation can only be consumed by a limited number of group members. Then the chance that an individual member of the group will benefit from the public good becomes the smaller the larger the group is. But this is not the case in the knowledge-exchange situation. The public good here (i.e. information available in the common pool) can be accessed by all group members, and its value is not diminished by the fact that it also used by others. This, so to speak, non-exhaustibility of the public good makes people's payoff independent of group size (Isaak, Walker & Thomas, 1984).

This independence of people's cooperation rate from group size in a knowledge-exchange dilemma was confirmed by an experiment. It made no difference if a participant was a member of a group of six people (working non-synchronously), or of a group of 50 people (working non-synchronously).

Awareness of the Importance of Information

Knowledge exchange through a shared database will in most cases imply an extremely anonymous type of communication. While speakers in face-to-face conversation receive verbal and non-verbal feedback if a message is understood, if it is relevant or not, these essentials are missing in a situation of knowledge exchange through a database (Kiesler, Siegel, & McGuire, 1984). Here, meta-knowledge, i.e. awareness of one's own expertise (Flavell & Wellman, 1977) and of the needs and expertise of others (Stasser, Steward, & Wittenbaum, 1995), plays a decisive role. Interacting groups will, in the course of time, build a "transactive memory", i.e. meta-knowledge about which specific information is available from which person or at which place. This transactive memory is an important factor of group performance (Littlepage & Silbiger, 1992). In the knowledge-exchange dilemma, the group's transactive memory is particularly important because a person may be more prepared to supply information to a database (which others can use) if that person is aware of possessing information which is so important that it will really help others to tackle their tasks. So we can assume that the more people expect that their knowledge is relevant to others, the more information will they enter into a database and make it available to others.

This assumption was confirmed in various experimental studies in which the experimental scenario was extended. In these experiments, Stage 1 distinguished between "important" and "less important" basic salaries. In the cover story, the "important" basic salaries were those of (fictitious) salespersons which had to be calculated urgently, i.e. those cases in which the corresponding total salaries were more likely to be calculated during Stage 2 than in the less urgent cases. In line with theory, our studies have confirmed a very stable effect in that people will enter much more important information than unimportant information. About 61 per cent of the important information was entered, but only 24 per cent of the unimportant information (Cress et al., 2006, Study 1).

Cost of Entering Information

Considering the payoff structure of the dilemma, it is not surprising that people tend to provide more important than unimportant information. If a person accepts bearing the cost of entering information into the database at all, it is a logical decision to do so in such a way that the group has the greatest benefit.

The situation is different, however, if entering important information leads to higher cost for the person who possesses that information (the "information carrier"). This might occur, for example, if preparing this information requires more time and effort. Then the information carrier has to decide either to accept these extra costs in order to give others greater advantage by supplying that important information, or to spare those extra expenses at the price of not giving the other group members maximum benefit.

This type of situation was reflected in the experiments by a condition in which entering "important" information into the database cost twice as much as entering "less important" information. In the former case, the participants had to wait for 20 seconds, in the latter only 10 seconds. A significant interaction occurred here. While in the equal cost condition, it was mainly important information that was entered, no such preference was observed in the condition with higher cost for entering important information (Cress et al., 2006, Study 2). Figure 2 shows this interaction.

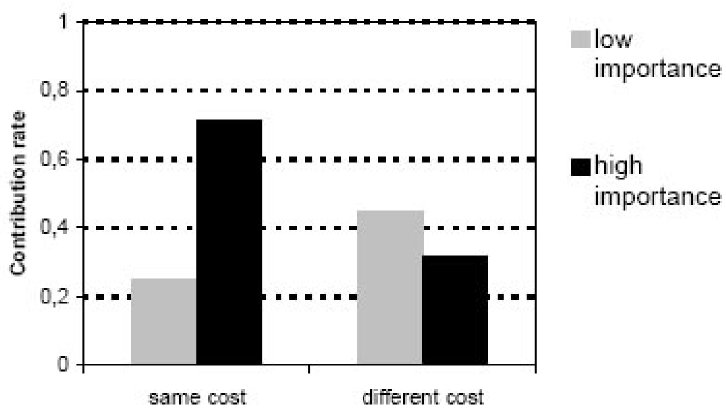

Figure 2. Significant interaction between cost of entering information and importance of information. When cost is the same, the rate of entering important information is significantly higher. This preference disappears in a situation in which entering important information leads to higher cost.

These findings show that in situations in which people have to accept extra cost for entering information that is relevant to others, they tend to be more egoistic: they will contribute less relevant information than in situations in which entering relevant information leads to no additional disadvantage.

Use-Related Bonus System

Not only a reduction of contribution costs may optimize the payoff structure, but also the implementation of some reward system. Some business companies have introduced bonus systems to reward their staff for sharing information. If such rewards are merely based on quantity, they may encourage people to enter mainly information which is of little relevance to other people, or in other words, to fill the database with "trash". It will in many cases make more sense to base such a reward system on quality or usefulness of the entries. One possibility to do this is a "use-related reward system". Here a person receives a bonus every time when another group member retrieves information that was provided by that person. When such a reward system is in existence, it will be in the interest of an information carrier to enter primarily those items which are relevant to others and, therefore, more likely to be retrieved.

One of our experiments tested the efficiency of such a use-related bonus system. Three conditions were compared: An environment with no bonus system, one with a bonus system that compensates precisely for the cost of entering information ("compensation bonus") and one which provides a bonus that exceeds the cost of entering information ("more-than-compensation bonus").

In terms of an objective payoff function (mathematically calculated), a social dilemma would no longer exist with this type of bonus system in both conditions. If the compensation bonus covers the cost of entering information into the database, cooperation is no longer a disadvantage from the user's point of view. With a more-than-compensation bonus, a user would even gain profit from database entries, as the bonus here is higher than the cost of providing these entries.

Interviews with users showed, however, that both types of bonuses were perceived as low. Neither the compensation nor the more-than-compensation bonus were perceived (subjectively) as really covering the cost. So – subjectively – both situations represented a social dilemma, even though – objectively – the payoff structure no longer reflected such a dilemma. Participants appear to be influenced by a misguided perception that even in this situation cooperation is an unfavorable strategy. Referring to people's behavior, the experiment revealed that the higher the bonus was, the more did users select "relevant" items of information for entering into the database (cf. Figure 3).

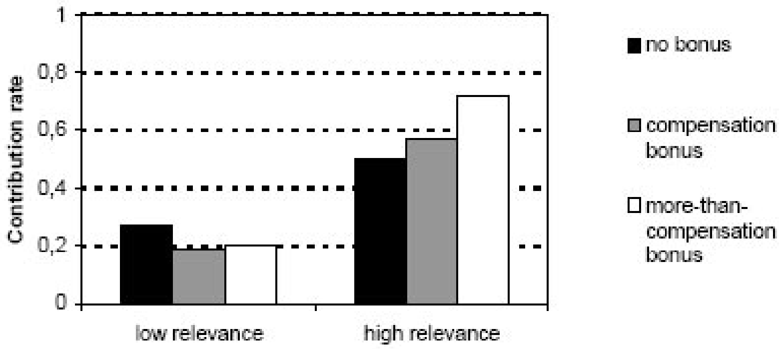

Figure 3. Significant interaction between amount awarded as use-related bonus, and relevance of information. The higher the bonus, the more relevant information will participants enter into the database.

Reducing Uncertainty through Feedback and Recommendations

If we compare the information-exchange dilemma to other social dilemmas, people not only have the choice between cooperation and defection. Any new information which they have at their disposal will allow them to take a new decision. People can select any proportion of their available knowledge to supply (or not supply) it to others. When they have taken such decision, they will not receive any immediate feedback on decisions taken by other people. Only after a certain period of time of having used the database, a user will get a – mainly vague – impression of the other users' behavior. The total number of all database entries will only permit a rough assessment of the extent to which the other people have been cooperative or defective. The larger the group is, the more difficult is a correct assessment of the other group members' readiness to cooperate. But a valid assessment of other people's behavior would be extremely important from the individual user's point of view, because in a situation of uncertainty people often model the behavior of others. If they feel that others are cooperative, they will also behave in a cooperative manner. If they feel that others defect, they will also show a more egoistic behavior.

To check this expected effect of feedback information about other people's behavior, a further experiment included a feedback tool, which provided each participant with information about the number of entries that other group members had supplied to the database. With the presentation of a diagram with two bars, one showing the number of that user's own entries, the other one the average number of entries provided by other group members, the users could compare their own behavior with that of other members. The following conditions were compared: in one condition, participants were told that the other group members had entered an average of three values. In the other condition, the information was that others had entered an average of eight values. As expected, both groups behaved differently: people who believed that the average of the others was eight, provided significantly more entries than those who assumed that the average of the other group members was three (Cress & Kimmerle, 2007).

Apart from providing feedback about the behavior of others, there is another possible way of reducing uncertainty. A recommendation might be given that proposes how many pieces of information a person should contribute. In a situation of uncertainty in which people do not know how to behave adequately, such recommendations act as anchors (Tversky & Kahneman, 1974). Accordingly, we can expect people in a social dilemma situation to stick to such recommendations even if it is evident that there are no sanctions for not obeying them. Further experiments confirmed the influence of a recommendation in the information-exchange situation. A recommendation that proposes entering many pieces of information – eight in this case – leads to significantly more entries than a recommendation that proposes only entering three pieces of information (Cress & Kimmerle, 2007).

What happens if both factors, recommendation and feedback about the cooperation rate of others, are provided simultaneously? Will their effects be additive or will they interact? An experiment in which both factors were manipulated in a 2x2 factorial design (with "high recommendation" / "low recommendation" and "high feedback" / "low feedback" levels) showed that the provision of recommendations does not interact with social feedback. Both forms of reducing uncertainty work independently. Both factors lead to significant main effects, but there is no interaction. But it was also found that neither a recommendation nor feedback will motivate participants to achieve such high cooperation rates as the recommendation and the feedback had proposed. In the high recommendation and high feedback conditions, eight entries were the recommendation or supposed average. Compared to the low recommendation and no feedback condition, this led to a significant increase of cooperation, but in all four groups the participants supplied far less than an absolute number of eight database entries.

Group Awareness

Computer-mediated communication is characterized by a high degree of anonymity of communication. If group members are located in different places and work on different assignments, they possess hardly any social cues about the existence of the others. "Group awareness tools" are frequently used in computer-mediated communication to make individual users aware of the existence and needs of other users (Carroll, Neale, Isenhour, Rossen, & McCrickard, 2003, Kimmerle, Cress, & Hesse, 2007). Such tools may provide pictorial representations of group members or information about these people and their activities. It is a wide-spread assumption that such tools will make the group more salient to individual users and increase their readiness to cooperate with the rest of the group.

But this is doubtful according to findings from social psychology. Group awareness tools will not in all cases improve cooperation, in some cases they may even induce the opposite effect. A social-psychological theory, the so-called SIDE model (Social Identity model of Deindividuation Effects, Lea, Spears, & de Groot, 2001), states that visual anonymity will not always be an obstacle to norm-conforming behavior. It may reinforce or diminish the influence of norms, depending on the predominant social or personal identity of the individual (Tajfel & Turner, 1979).

In the anonymous situation, people who regard themselves as group members will perceive the group as a very homogenous entity. This is due to the fact that they have no other information about the other people, apart from the fact of their membership of the group. Once anonymity is lifted and group members appear as distinct individuals, the group appears as much more heterogeneous. This makes the group norm less binding. So if cooperation is the group norm, reducing anonymity may lead to more egoistic behavior. With people who perceive themselves primarily as individuals, the reduction of anonymity leads to the opposite effect. In the anonymous situation, these people are hardly aware of the existence of other people. If anonymity is lifted and other group members become visible (say, through pictures), the existence of these other people is perceived more strongly. Such individuals will now tend to behave as group members who are more inclined to assist others.

This assumption was tested in an experimental study (Cress, 2005). "Social value orientation" (McClintock, 1978) was measured to distinguish between two categories of people, those who perceive themselves as group members (pro-socially oriented people) and those who perceive themselves as individuals (individually oriented people). This social value orientation is a personality trait, describing if persons tend to act according to their own interests or to those of others in social situations. In the experiment, one environment was used which displayed pictures of the other group members on the screen. The other environment did not provide any pictures. Figure 4 shows that the assumptions made by the SIDE model were confirmed. Apart from the general main effect of social orientation (pro-socially oriented people are more cooperative than individually-oriented people), the experiment also demonstrated a significant interaction effect: pictures of the others increased cooperation from individually-oriented people, but led to a decline of cooperation from pro-socially oriented people.

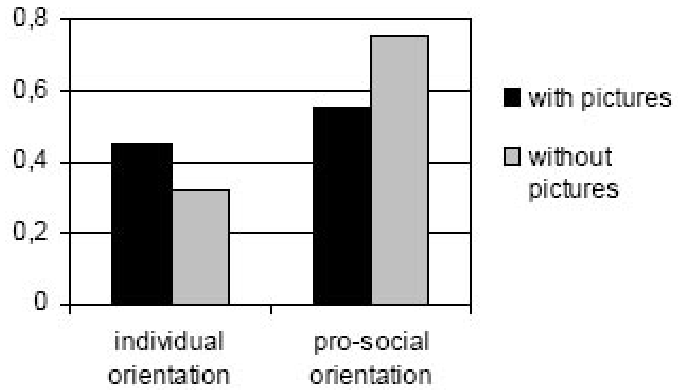

Figure 4. How pictures of group members influence people with individual and pro-social orientation. Significant main effect and significant interaction effect.

The results show that the provision of group-member pictures has two different effects. The database users get aware of the existence of other group members (leading to higher cooperation from individualists) and they get aware of their heterogeneity (reducing cooperation from pro-socials). One possible conclusion is that visualizations of group members will promote cooperation from all types of users if they portray the group members, to the greatest possible extent, as a homogenous group. In virtual worlds people may not only be represented by real pictures (say, photographs) but also by avatars, i.e. graphical representations or figures, so this idea may be implemented by using identical avatars for all group members.

Some Practical Consequences

Which conclusions may be drawn from these results for forums, wikis, databases and other communication tools?

First of all: we have to be aware that through such channels a lively exchange of knowledge will not occur automatically, even if technical systems make it easy to establish a shared knowledge pool and if people have easy access to that pool – say, by using Web 2.0 tools – and can enter information easily. For a group of users – a workgroup, business company, online community etc – the existence and availability of such a pool is extremely efficient, but participation may be unattractive from the individual user's point of view. As soon as an individual has to spend time and effort for giving away information and may lose power by doing so, a social dilemma will occur, which will prevent active participation in knowledge exchange by contributing one's own information. In such a situation, people who possess knowledge will give it away primarily under conditions which imply positive consequences for themselves. So what opportunities exist to demonstrate to such users the benefit of their own active participation?

An attempt may be made to change the structure of the dilemma situation. One way is to reduce the cost of passing on one's knowledge. It is also possible to provide some additional benefit. Knowledge carriers may, for example, regard the passing on of knowledge as an opportunity to establish a positive reputation within their community. Being regarded by others as an expert and competent colleague, is very attractive in the eyes of most people.

But such structural modifications will not completely remove the dilemma, because as soon as people are confronted with any costs of their contributions, they will have the impression of being in a social dilemma. Social-psychological approaches may be relevant here: people will be more cooperative if they take into account not only their own interests, but also the benefit of other participants. In knowledge transfer situations, the group and other group members and their needs should be as salient as possible. This will work best if the group works for a common goal and there is a high degree of group identity and reciprocity. A norm or recommendation to propose high cooperation should also exist at the same time.

The questions which were dealt with in this article will continue to play an important role in the future, both in simple forms of knowledge transfer and in computer-mediated collaborative construction of new knowledge. Motivation of the participants, their readiness to cooperate actively, will always be a fundamental requirement of successful knowledge processes.

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Social Networking and Education: Emerging Research within CSCL

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Abstract: In this paper I introduce a youth-initiated practice: online social networking that is transforming our society in important ways and has vast implications for learning research and education. I introduce the social and technical features that characterize social networking systems and outline results from emerging research that suggests the social and intellectual practices in which participants naturally engage and how these relate to the competencies increasingly valued in formal education. Next, I discuss one research projects which I am currently pursuing that build on early work and suggest how educational programs might employ such practices to advantage. Finally, I discuss what I see as the educative value of this technology in certain contexts and suggest a course for future research and development. My overall goals are to inform other researchers interested in pursuing similar projects and to stimulate interdisciplinary conversation about where such agendas fit within and advance the aims of CSCL.

Social Networking Systems: The Next Wave of CSCL?

Recent conference symposia, papers and journal articles within the CSCL community have demonstrated keen interest in learning from students' everyday out-of-school socio-technical practices about how to better develop future technology-powered contexts for learning (Barron, 2006; Fields & Kafai, 2007; Forte & Bruckman, 2008; Gardner & Kolodner, 2007; Halverson, 2007; Miyake et al., 2007; Peppler & Kafai, 2007; Steinkuehler, 2007; Yardi & Perkel, 2007). One example of this include Steinkuehler's research on online game-playing "in the wild," a goal of which is to inform the design of intentioned learning environments in school and after-school contexts. Similarly, Forte and Bruckman (2008) examined authorship and editorial processes in Wikipedia to generate new methods for assessing user-generated content in classrooms. Peppler and Kafai (2007) investigated youth's creative media production after-school with Scratch design software to suggest new directions for media literacy education, and Barron (2006) tested a learning ecology framework to ultimately address inequities in school-based learning opportunities.

In this vein, I introduce another youth-initiated technology-enabled practice: *online social networking* that is transforming our society in important ways and has vast implications for educational research and pedagogy. In this paper, I introduce the social and technical features that characterize such systems. Next, I outline results from emerging research that suggest the social and intellectual practices in which participants naturally engage and how these relate to the competencies increasingly valued in formal education. I discuss one research projects which I am currently pursuing that build on this research and suggest how educational programs might employ such capacities to advantage. In closing, I discuss what I see as the educative value of this technology and suggest a course for future research and development efforts. My overall goals in this paper are to inform other researchers interested in pursuing similar projects and to stimulate interdisciplinary conversation about where such agendas fit within and advance the aims of CSCL research.

Social Networking Sites (SNS): A definition

According to boyd & Ellison (2007) an online *social network* site is a "web-based service that allows individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system" (p. 1). Other terms used to characterize such services are *social digital technologies* (Palfrey & Gasser, 2008), *participatory media* (Bull et al., 2008) and *social media* (Barnes, 2006). Whereas this term "social network" site seems to reflect the fact that these sites represent existing social bonds, another term commonly used, "social networking" implies that people use these websites in order to forge new networks. For instance, LinkedIn is a social networking site tailored to business people seeking to make contact with those within and outside of their usual network of colleagues and customers. Other sites, such as Facebook and MySpace, have features that support maintaining existing social bonds, such as the ability to join online groups of people who are already in one's offline network (e.g., a high school alumni group, a sports team, etc.), as well as creating new bonds (e.g., the browsing feature, groups feature, etc.). In this paper, I use the term social networking site (SNS) to describe an online Web-based service with the features described above and through which users maintain existing social ties and develop new ties with people outside their network (Jones, Millermaier, Goya-Martinez, & Schuler, 2008).

What distinguishes online social networking sites from other forms of virtual communities is that they allow users to articulate and display their social connections (Donath & Boyd, 2004), similar to allowing others to view your Rolodex, or contact list, and interact with it online. In this way our connections are made visible and potentially become the connections of our "friends, and who we are – our online identities- are visibly linked to who we know. Boyd & Ellison (2007) suggest that interactions through social networking sites can result in more and different types of connections that would not otherwise be made. In addition to individual profiles, SNSs may include profiles of bands, companies, events, non-profit organizations or political parties. Social networking sites can serve a range of purposes, including helping users maintain existing friendships (Ellison, Steinfield, & Lampe, 2007) or forge new relationships based on shared professional goals, political views, a common language or shared racial, sexual, religious, or cultural identities (boyd & Ellison, 2007).

Since rising to mainstream adoption in 2003, online social networking sites have attracted millions of users. Two of the most commonly known are MySpace and Facebook, with the former comprised of 125 million unique users worldwide ("*Comscore*," n.d.) and with Facebook comprised of 200 million unique users worldwide (Comscore, 2009). (In comparison, the current total U.S. population is 300 million) (Stone, 2008). Launched in 2003, MySpace recently generated more page views than Google and has users across all age ranges, but young people (12-17) and (18-34) make up its largest share (73%) of users (Compete, 2008). In fact, the majority of online teens (55%) in the U.S. have created a personal profile within an online social networking system (Lenhart & Madden, 2007) and visit their SNS daily or several times a day, devoting an average of 9 hours a week to the network (National School Boards Association, 2007). The percentage of college students, ages 18-24 who are using these technologies may be even higher than the U.S. teen data. A study of undergraduates enrolled in four- or two-year colleges and universities in the U.S., released in October 2008, found 85% of respondents use social network sites, and most used these on a daily basis to communicate with others (Salaway, Borreson, Nelson, 2008).

Popular media accounts of these technologies have frequently painted a negative image. They are commonly depicted as a passing fad, a waste of time, or harmful stomping grounds for fakesters, cyberbullies, and sexual predators. Despite these accounts, fields outside education are discovering that these technologies also have benefits as they are increasingly integrated into economic, cultural, and political processes, helping to transform not only daily practices but the very principles that govern them. For instance, despite the economic downturn, businesses are sustaining or increasing their investments in online social networking systems to tap their employees "social connections, institutional memories and special skills – knowledge that large, geographically dispersed companies often have a difficult time obtaining" (Stone, 2008, p. C2). The "hot spots "of innovation that emerge when traditionally disparate entities have the means to coalesce personally and professionally are generating revised notions of how generative collaborations occur and in turn, revised management philosophies and business practices (Gratton, 2007). In journalism, news media are increasingly tapping viewer participation in the form of online comments and testimonials, independently produced videos, and citizen journalist blog entries to enhance the accuracy, power and spread of centrally produced stories (e.g., CNN's documentary *Black in America*). And of course, apparent in the 2008 presidential election campaign was a new style of "Netroots" politics where potential voters don't just consume campaign propaganda but help shape and distribute it via online meet-ups, blogs and user-generated videos embedded within social network sites (Sheehy, 2008, p. 79)

Although much of the published research on the use of social network sites is still emerging, the phenomena emerging around them is driving cutting edge research in communications, information science, sociology, economics, political science, cultural studies, and computer science and is both conceptual and empirical in nature (boyd & Ellison, 2007). Few studies explore the link between SNS use and education (e.g., see boyd & Ellison's comments on the lack of research in this area). Given the overwhelmingly apparent interest in SNSs among high school age youth and the emphasis on developing 21st century competencies — which assume collaborative problem solving, multimodal communication, technological fluency, and digital citizenship skills — for academic success in the digital age, SNS use among high school students seems an important topic for CSCL researchers to examine. Next, I outline results from one such study and discuss a future agenda in the context of one recently funded project.

Social Networking Sites & Learning: An Overview of Emerging Research

To date, a research-based discussion of SNSs and education has been virtually nonexistent. A search of five educational databases and table of contents analysis in several major educational/educational technology/learning sciences research journals (2004-2008) found little empirical work that addressed what, if anything, students might be learning within the hours they spend engaged in these sites. Moreover, popular essays and reports use findings from large survey studies in order to make conceptual arguments (National School Board Association, 2007)

To understand how social network sites functioned for what purposes and with what results in the lives of urban youth (17-19 years old), we undertook an 18-month investigation of the SNS-using practices among students from low-income families, an adolescent sub-group of increasing interest but relatively underexplored in the learning sciences literature (Barron, 2006). We began by surveying them in the winter of 2007 (n=832) and again, in the winter of 2008 (n=600) on their Internet and technology access, conditions, and use, including their use of social network sites (Greenhow, Walker & Kim, under review; Greenhow, Kim & Robelia, 2008). We followed up on trends seen in the survey data using focus groups and semi-structured, in-depth interviews with a selected sub-set of students who were all predominantly MySpace users. To explore in depth what the students were telling us and identify whether, in fact, they were engaging in social and intellectual practices of interest to education, we conducted talk-alouds (Clark, 1997) and content analysis of students' SNS pages with this same sub-group of users, adapting a coding scheme developed by Jones et al. (2008). Findings from these exploratory studies revealed several benefits to students' integrating social network sites into their lives (Greenhow & Robelia, in press-a; Greenhow & Robelia, in press-b) and suggest directions for the design of future research and educational environments (Greenhow, Robelia & Hughes, 2009).

We found that students' participation in social network sites involved operating within various technical and social affordances and limitations and that such participation could have potential learning benefits. For instance, communicating through these spaces, students: maintained various types of relationships (e.g., *strong* and *loose interpersonal connections*) to meet a range of needs, such as obtaining *emotional* and *cognitive* support; they experimented with their SNS as a platform for *self-presentation* (Greenhow & Robelia, in press-a). Using their SNS outside of school, students formulated and explored various dimensions of their identity and projected these to multiple audiences, a communicative affordance previously only available to a privileged few.

Students also used their online social network to fulfill essential social learning functions, including obtaining *peer support* for *creative endeavors* and *help with school-related tasks*. Within their SNS, students engaged in a complex array of communicative practices. They believed their regular use of social networking sites was developing their creativity, communication skills, technology skills, and openness to divergent viewpoints (Greenhow & Robelia, in press-b). However, more research is needed to understand whether and how such socio-technical practices fit within students' overall learning ecology (Barron, 2006) and complement – or be designed to enhance –the competencies educator's value (e.g., new literacy practices, technological fluencies, collaborative problem-solving approaches). Such research initiatives might also suggest how current institutionalized approaches to teaching and learning might shift to accommodate such change (Greenhow, Robelia & Hughes, 2009).

Designing Social Networking Platforms for Learning

We aim to develop this research, specifically targeting students from low-income families and hone our research questions about their participation and learning within SNSs *in situ*. In addition, we aim to investigate similar questions with different populations of high school and college undergraduate social media users. Our ultimate goal is to understand how these technologies, and students' use of them, may be adapted for different social and learning purposes across the secondary to postsecondary experience.

In our current Youth and Social Media project, funded by the John S. and James L. Knight Foundation, we are developing an informal learning environment for high school and college undergraduates, ages 16-25, that involves SNS technologies. This social media environment, called *Hot Dish* (http://apps.facebook.com/hotdish/) is located within the largest worldwide online social network: Facebook.com, and features social networking around a particular content area (i.e., environmental science news, research, and activist-oriented "challenge" activities) rather than school or geographic location. Over a 9-month period, we are studying young people's participation in *HotDish* (and one other site we are still developing), focusing specifically on: (1) how students engage with the content (both editorial and user-generated) to develop their knowledge of environmental science concepts, issues, and green consumerism; (2) how community develops, if at all, in such spaces; (3) characterization of users' literacy practices; and (4) real world impact of "challenge" activities. We seek to understand whether there may be unique advantages to locating similar sites that may be designed, within existing social network sites and if so, what those advantages may be. Although our study is grounded in the CSCL, learning technologies, New Literacies, and new media/communication studies literature, we know of no other studies currently examining such issues among students, and in this, our study will break new ground.

Avenues for CSCL Research

CSCL is concerned with how people can learn together with the help of computers and the Internet (Stahl, Koschmann & Suthers, 2006). According to Stahl and Hesse (2006), much of CSCL research focuses on:

> …the individual learner or on local interactions in dyads and small groups. The role of technology is conceptualized as mediation by affordances or artifacts, which exist within socio-cultural contexts, influenced by…large-scale factors.

CSCL emphasizes collaboration, knowledge-building, and learning together through individual and group processes of negotiation and meaning-making, mediated by technologies, in formal and informal educational contexts (Stahl et al., 2006). Social networking technologies, or their coming iteration, *social operating systems*, and their interface with other technologies (e.g., virtual worlds), may create opportunities for supporting CSCL in ways we have not seen. What research questions and avenues might CSCL take up with respect to these emergent socio-technical spaces and the issues they raise? What might we gain in doing so? Due to space constraints, I will merely list initial thoughts here, but will elaborate on these and others in the final presentation and ask my colleagues to join with me in sharing their knowledge, experiences and ideas.

One strand of research might involve analyzing -- and defining methods for analyzing -- the individual and group meaning-making activities and artifacts that occur *naturally* within environments involving SNS features, attending especially to how the features and practices seemingly unique to such environments contribute to bringing these about. Increasingly, environments involving SNS features have built-in data-gathering and visualization capabilities (e.g., Google and Facebook analytics and related network-mapping tools). Research initiatives might also seek to define and describe how these capabilities might align with and advance CSCL purposes.

A second strand of research might involve design-based research projects where CSCL principles and insights from the existing SNS literature across disciplines are synthesized to generate guidelines for the design of promising learning environments with strong visual elements (not just text) and personal / inter-personal profiling and contributions. Results from such experimentation might then suggest new avenues for learning environment research and design, avenues that take advantage of recent technological advancements, or suggest new paths for pedagogical theory or school policy (e.g., intellectual property, digital citizenship, Internet safety policies).

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Learning and Knowledge Building with Social Software

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Abstract: The progress of the Internet in recent years has led to the emergence of so-called social software. This technology concedes users a more active role in creating Web content. This has important effects both on individual learning and collaborative knowledge building. In this paper we will present an integrative framework model to describe and explain learning and knowledge building with social software on the basis of systems theoretical and equilibration theoretical considerations. This model assumes that knowledge progress emerges from cognitive conflicts that result from incongruities between an individual's prior knowledge and the information which is contained in a shared digital artifact. This paper will provide empirical support for the model by applying it to Wikipedia articles and by examining knowledge-building processes using network analyses. Finally, this paper will present a review of a series of experimental studies.

Introduction

A fast development of the Internet could be witnessed in recent years. New tools and services, so-called *social software* technologies, such as weblogs, wikis, folksonomies, podcasts, file sharing, or virtual online worlds are changing their users' handling of data, information and knowledge (Kolbitsch & Maurer, 2006). Nowadays, users are actively involved in creating Web content. The distinction between producers and consumers of knowledge will not make sense any more. Content is linked beyond the limitations of single tools by using open interfaces. Desktop computers as individual repositories tend to be replaced by the Web (O'Reilly, 2005). This development has a strong impact on individual learning (Sigala, 2007). Individuals can participate in a collective advancement of knowledge and, in addition, they can benefit from an enormous amount of knowledge which is available globally.

In terms of constructivism, learning is intensified by what is offered through the World Wide Web: people participate in self-regulated learning in informal learning environments, as members of a *community of knowledge*. The world-wide availability of social software tools opens up a new dimension of knowledge processes: large numbers of users can work together on shared digital artifacts (Tapscott & Williams, 2006). This does not only lead to accumulation of knowledge (the knowledge of many individuals is brought together and is made available to others) but also to emergence, i.e. the creation of new knowledge (Johnson, 2002), a process that is being discussed using keywords like *wisdom of the crowds* (Arazy, Morgan, & Patterson, 2006; Surowiecki, 2005). But practice with many social software applications has shown that new knowledge will not emerge automatically due to large numbers of collaborating users. Web 2.0 environments will not necessarily lead to an optimal individual learning process, and it is not very frequent that new knowledge is in fact being developed within a social software community.

Accordingly, the question is under which circumstances these emergent phenomena do happen and social software tools can actually become promoters of knowledge advancement. In order to illustrate processes of knowledge progress and the conditions that facilitate it, we will present a framework model that describes and explains learning and knowledge-building processes with shared digital artifacts. This model is based on the systems-theoretical approach by Luhmann (1995) as well as on the model of equilibration by Piaget (1970). The following section will present the framework model, starting with a brief summary of the underlying theories followed by the description of our model. The *content analyses* section will discuss empirical evidence for the validity of this model, based on content analyses of Wikipedia articles. The *network analyses* section describes co-evolution of social systems (knowledge building) and cognitive systems (individual learning), referring to an example from Wikipedia as well. The *experimental studies* section will present findings from experiments under laboratory conditions. The article will conclude in a section that summarizes and discusses our considerations and findings.

Individual Learning and Collaborative Knowledge Building

Our framework model which we will present in this section is based on systemic and cognitive approaches to describe processes of collaborative knowledge production. Based on a systems-theoretical considerations, the model describes shared digital artifacts (developed with the help of social software tools) and their respective communities as social systems in terms of Luhmann (1984, 1986). In order to describe the processes that change such a social system and the cognitive systems of individual users, the model refers to Piaget's concept of equilibration (Piaget, 1977a). Thus, the following paragraphs will first give a brief review of the approaches by Luhmann and Piaget before presenting an integrative framework model by Cress and Kimmerle (2007, 2008).

Systems Theoretical Considerations

Luhmann's theory distinguishes between "system" and "environment" (Luhmann, 2006): whatever does not belong to the system is part of its environment. A system consists of operations which create the difference between the system and the environment (Luhmann, 1984). The mode of operation of a social system is *communication*. Cognitive systems, however, operate via processes of consciousness and cognitive processes. Systems are autopoietic (Luhmann, 1984; cf. also Varela, Maturana, & Uribe, 1974). They are able to produce and reproduce themselves, hence guaranteeing their own existence (Luhmann, 1990). A system is not in an direct exchange with its respective environment, rather it is *operatively closed*. This operative closeness of systems excludes communication between autopoietic systems, since they operate in different modes. What we can still observe, however, is that a system is influenced by other systems and reacts to its environment.

Luhmann has dealt with this issue by stating that a system is both open and close, using the concept of structural coupling (Luhmann, 1992). *Structural coupling* is based on the structure of expectations that a system creates, which make it sensitive to *irritations* from the environment of that system (or from other systems respectively). Irritations from the environment will be transferred into the mode of operation that is inherent in that system. From the system's point of view, the environment will always be more complex and more chaotic than the system itself. The system will need to reduce this complexity by distinguishing between what belongs to the system and what does not.

In addition, reduction of complexity is a prerequisite of emergence (Kofman & Senge, 1993). Emergence refers to systems with hierarchical structure in which features may occur at the higher level of the system which cannot be explained by features of the lower level of the system. These higher-level features are created by synergies between elements at the lower level of the system. Only holistic considerations make it possible to explain phenomena of emergence. This cannot be achieved by a reduction into partial systems or subsystems. Luhmann's theory is capable of describing computer-mediated construction and communication of knowledge. Shared digital artifacts (and their respective communities) may be understood as social systems that use written communication as their mode of operation. Communication is mediated, using shared digital artifacts, and the system is structurally coupled with the cognitive systems of its users.

Equilibration Theoretical Considerations

Luhmann is particularly interested in social systems. Other constructivist theoreticians, however, are more interested in psychological aspects. A constructivist approach that is highly relevant in order to understand processes of learning is that by Piaget. This approach explains how a cognitive system deals with "irritating" information from its environment. Piaget describes qualitative changes of cognitive schemas in the course of an individual's development (Piaget, 1977b). Cognitive schemas structure and simplify stimuli from the environment and help individuals to understand them. Thus, according to Piaget, knowledge is always a construction of one's environment, i.e. an interpretation of one's experience of the environment, with the help of cognitive schemas. Knowledge construction, then, is an increasingly more flexible application, adaptation, and modification of cognitive schemas. According to Piaget, the mechanism is as follows: an individual's experiences with the environment may lead to perturbation of this individual's cognitive balance ("equilibration") or, in other words, to a *cognitive conflict*. As a result, the individual's own cognitive schemas will no longer fit her or his experiences with the environment, requiring re-equilibration.

Here, Piaget distinguishes between two functions: assimilation and accommodation. *Assimilation* means active shaping of the environment by interpreting and explaining current experiences, giving them a place in existing schemas. *Accommodation* means adaptation to the environment in the form of qualitatively changing one's own cognitive schemas.

Integrative Model

In their framework model Cress and Kimmerle (2007, 2008) integrate the systemic and the constructivist approach. The authors have explained their model of knowledge building by referring to wikis as a prototype of a social software tool. They distinguish between two systems in terms of Luhmann: the social system (content of the wiki and the associated community) on the one hand, and the cognitive system of an individual on the other hand, meaning this person's declarative knowledge in semantic memory (Tulving, 1985). Since these two systems are both operatively closed, they cannot be transferred into each other. But they can both be developed further by means of structural coupling. This structural coupling is enabled by the exchange processes that occur between the cognitive system of the individual and the social system wiki. With respect to these exchange processes a distinction has to be made between externalization and internalization of knowledge.

In the course of externalization, a user will supplement or modify a wiki article on some topic by using his or her own knowledge. After that, this knowledge exists independently of the user in the form of information in the wiki where it is accessible to anyone. This externalization process will not only bring about an increase of information in the social system wiki, it leads to the development of knowledge in the individual user's cognitive system as well. Externalization of somebody's own knowledge requires that a person deals in more depth with existing knowledge and considers it more thoroughly (Hayes & Flower, 1980), and this will lead to a re-alignment or improvement of cognitive schemas. Writing texts and working with them becomes a tool for individual knowledge acquisition (Tynjälä, Mason, & Lonka, 2001). The second process is internalization of information from the wiki. Pieces of information from the wiki are decoded and incorporated into existing internal knowledge structures. This will create new knowledge entities in that person's cognitive system, new associations between knowledge entities and new schemas.

The model by Cress and Kimmerle specifies the mechanisms of internalization and externalization. It expands Piaget's model by describing accommodation and assimilation not only from the perspective of an individual's cognitive system, but also from that of a social system. Users assimilate information from the artifact into their own cognitive schemas, and they accommodate by modifying their schemas induced by information from the wiki. An analogous process of assimilation may take place in the social system: users add pieces of information from their own knowledge, which will, however, not change the basic message and structure of the wiki, only add additional aspects. Accommodation is also possible in a wiki if users contribute their knowledge in such a way that the entire message is changed completely and, sometimes, new structures are being created. Accommodation tends to result in some qualitative modification of the artifact, whereas assimilation has to do with quantity, introducing new aspects or examples but no fundamental innovation.

As a consequence of the processes of internalization and externalization, both the social system wiki and the cognitive systems of the individuals involved will develop further. Both systems will mutually influence each other, and as a result of the difference between the two systems (in Luhmann's terminology: the boundary between the systems) new knowledge will be generated. What occurs is co-evolution of the two systems, which can be regarded as the result of structural coupling. The newly generated knowledge is emergent: it was previously neither part of the cognitive system nor of the social system, it can merely be explained by looking at both systems simultaneously (cf. also Holland, 1998).

Content Analyses

Citing various Wikipedia articles as examples, Cress and Kimmerle (2008) were able to demonstrate what these processes of assimilation and accommodation, as described above, can mean in practice for a shared digital artifact. For example, processes of equilibration could be observed in the English-language Wikipedia article on "AIDS origin". This subject is a matter of controversial discussion, which finds expression in a large number of modifications on the Wikipedia page. These consist both of assimilations and accommodations. An assimilation, for instance, is the following alteration which simply adds two items to the list of abbreviations [11, p. 116f]:

"*In Russian it got the name SPID (Sindrom Priobretyonnoy Immunitetnoy Defitsitnosti)." (10 February 2007). "… and in Irish SEIF (Siondróm Easpa Imdhíonachta Faighte)*". (6 May 2007).

At the same time, however, processes of accommodation could also be observed. An example is the case of a controversial theory which was introduced into the article. 'This theory assumes that research on substances for polio vaccination was initially accountable for transmitting the AIDS virus to humans. One sentence in the article: "*[The viruses] most likely got into humans via the hunting and eating of the original primate species*" was changed as follows to leave more room for other explanations: "*Possible ways for this virus to have originally infected humans include the hunting and eating of the original primate species*" (3 March 2006). Afterwards, the whole approach of the explanation is modified: "*A more controversial theory known as the OPV AIDS hypothesis suggests that the AIDS epidemic was inadvertently started in the late 1950s in the Belgian Congo by Hilary Koprowski's research into a polio vaccine*" (28 November 2006). Reference is made, once again, to a theory that had already previously (20 February 2006) been described as follows:

"*One currently controversial possibility for the origin of HIV/AIDS was discussed in a 1992 Rolling Stone magazine article by freelance journalist Tom Curtis. He put forward the theory that AIDS was inadvertantly caused in the late 1950's in the Belgian Congo by Hilary Koprowski's research into a polio vaccine. Although subsequently retracted due to libel issues surrounding its claims, the Rolling Stone article encouraged another freelance journalist, Edward Hooper, to travel to Africa for 7 years of research into this subject. Hooper's research resulted in his publishing a 1999 book, The River, in which he alleged that an experimental oral polio vaccine prepared using chimpanzee kidney tissue was the route through which SIV mutated into HIV and started the human AIDS epidemic, some time between 1957 to 1959.*"

Here, various stages of accommodation can be observed, in which a new idea is presented, then qualified to some extent, and finally integrated into the text in such a way that it supplements other theories. Further examples of assimilation and accommodation processes in Wikipedia can be found in Cress and Kimmerle (2008).

It is, however, not only interesting to look at modifications of the shared digital artifact, it is also important to look at the corresponding changes in the cognitive systems of users. One technique to study this co-evolution of cognitive and social systems – using Wikipedia articles as well – will be described in the following section.

Network Analyses of Wikipedia

Network analyses (Wassermann & Faust, 1994) were able to demonstrate that changes of the content orientation of related Wikipedia articles were accompanied by similar changes in the orientation of the users who were involved (Harrer, Moskaliuk, Kimmerle, & Cress, 2008). The development of this co-evolution was illustrated on the basis of the article on "schizophrenia" in the German-language version of Wikipedia. This topic is particularly appropriate for initiating socio-cognitive conflicts and, consequently, equilibration efforts, since different approaches exist to explain what causes schizophrenia, which are the subject of controversial discussion. One approach deals with biological and genetic aspects, another one with social causes of schizophrenia, and the so-called diathesis-stress model combines these two explanations. There is also a psycho-analytical model of explanation, which is, however, less accepted.

To examine the co-evolution of cognitive and social systems, it was studied how the Wikipedia page on schizophrenia (and articles linked to this page) changed in the course of time. At the same time a closer look was taken on the development of the views of participating authors. In order to analyze developments of the artifact, all articles that were linked to the schizophrenia page were rated by experts to which explanation model (biological/genetic, social, or psycho-analytical) they belonged. These articles and the links between them were treated as the artifact network that was of interest here. In the visualization, the size of a page is an expression of the number of links that refer to that page. Visualization of the development of wiki pages and their links provides a representation of the development of the social system. In order to analyze the authors of these wiki articles, attention was paid to the topics of their articles and revisions in the course of time.

With respect to the shared digital artifact, the network analyses were able to show clear-cut effects. Comparing, for example, the artifact networks in 2007 and 2008 (as on 1 January respectively) revealed significant changes. In 2007 the social and the biological cluster were still obviously separated (see Figure 1). The social cluster, as it appears on the top of Figure 1 ("s-cluster"), includes pages on "*Paul Watzlawick*", "*Metakommunikation*" (*meta communication*), or "*Doppelbindungstheorie*" (*double-bind theory*). The biological cluster, further down on the right hand side ("b-cluster" in Figure 1), includes topics such as "*Temporallappen*" (*temporal lobe*), "*Amygdala*", and "*Nervensystem*" (*nervous system*). The psycho-analytical cluster ("p-cluster" in Figure 1), is represented by pages on "*Psychoanalyse*" (*psychoanalysis*), "*Sigmund Freud*", and "*Über-Ich*" (*super-ego*).

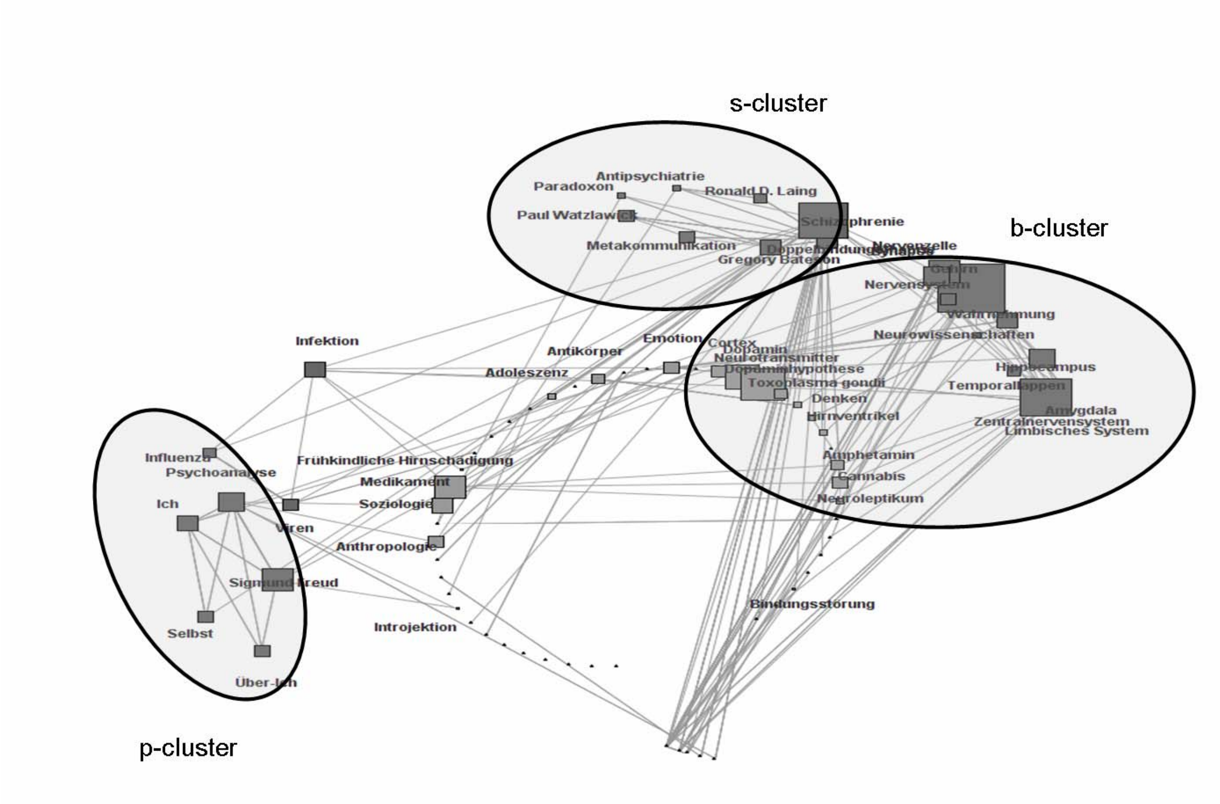

Figure 1. Artifact network 2007.

But with respect to the year 2008, the right hand side of Figure 2 contains a large common cluster which consists of both the articles on social and biological causes (“merged b+s-cluster”). The psycho-analytical cluster (“p-cluster”) still stands on its own and is barely linked to the rest.

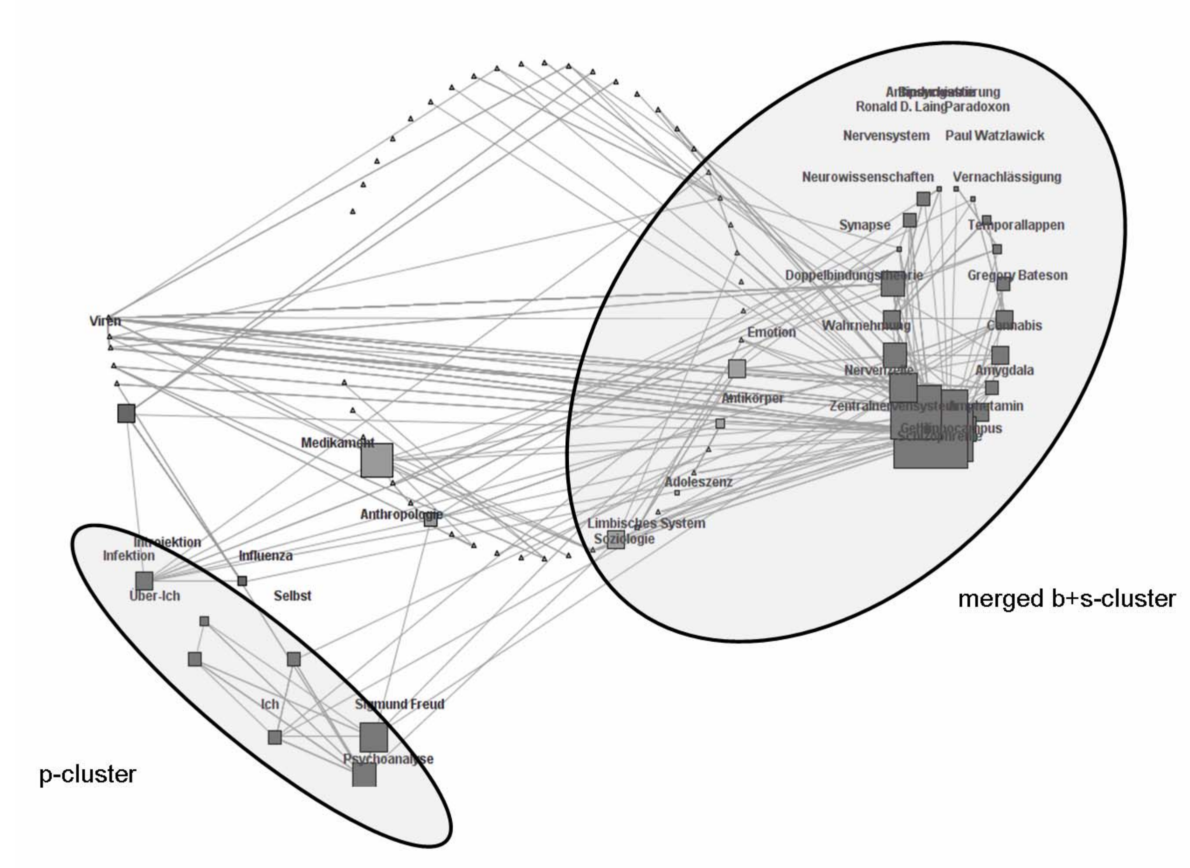

Figure 2. Artifact network 2008.

This is in line with a general tendency in literature on schizophrenia: the diathesis-stress model (which supposes that there are both biological and social causes) has become the major explanation, whereas the psycho-analytical approach tends to be regarded as an outsider position.

Particularly interesting in this context is the fact that an analogous development as in the Wikipedia articles has also occurred with respect to the authors who contributed to these articles. It could be shown that various users who originally had been involved in articles on either biological or social aspects seemed to have adopted a more integrative viewpoint in the course of time (Harrer et al., 2008). But with Wikipedia authors who had mainly been involved in psycho-analytical pages no such development could be observed.

So here, the question is how such co-evolution between cognitive and social systems is induced. One feature which is regarded as an important starting point of internalization and externalization processes and – in this way – of individual and collective learning was examined in a series of laboratory experiments, which will be presented in the following section.

Series of Experimental Studies

The mainspring of this co-evolution, according to the model by Cress and Kimmerle, is incongruity between the information contained in the shared digital artifact and the previously existing knowledge of somebody who reads that information. This will lead to a cognitive conflict of that user to which this individual will react with equilibration in terms of Piaget. The model uses an analogy to the work of Berlyne (1960) and Hunt (1965) assuming that there is a relationship between this incongruity and the extent of knowledge development which may be visualized as an inverted U-shape: low incongruity will not lead to perturbation of the cognitive balance, users will not experience a cognitive conflict, adaptation is not required. In the case of very high incongruity it will be difficult to link new information with existing knowledge; this will prevent accommodation or assimilation as well. Medium incongruity, however, is ideal to support the construction of new knowledge.

In order to allow empirical investigation of this model, an experimental paradigm was created. To operationalize the model, it was necessary to find a knowledge domain in which it is possible to distribute various knowledge items systematically between different people and the shared digital artifact. Again, schizophrenia and the question what causes this disorder was selected as a suitable knowledge domain. In order to create experimental material, extracts were made from textbooks on clinical psychology, presenting four arguments of about the same length on social explanations of the disease, four arguments on biological explanations and two arguments on the diathesis-stress model. Each of these ten arguments was complete in itself. This was the information base for a newly created digital artifact (wiki article on causes of schizophrenia) accompanied by what purported to be “newsletter articles” that were presented to participants, which they could then use as their own “previous knowledge” when working on the artifact.

Each of the three experiments was conducted in groups with five to ten participants. Going through the experiment took about two hours. Mobile computers were used for presenting two questionnaires (at the beginning and end of the experiment), for the instructions, and for a short tutorial which introduced the handling of the wiki. Participants were first provided with information contained in the newsletters; each of these covered one item of information (the substance of these newsletters contained the same information as the corresponding wiki entries, but the newsletters had been enriched with additional information). Then, participants had access to the wiki, which contained a varying number of information items, depending on the experimental condition. Participants were instructed to work on the wiki for 50 minutes. After that, the following dependent variables were measured:

- Internal assimilation: Factual knowledge about the arguments on the causes of schizophrenia (knowledge test with 15 multiple choice items).
- Internal accommodation: Conceptual knowledge about the role played jointly by diathesis and stress in causing schizophrenia. This conceptual knowledge was operationalized by using an open question on causes of schizophrenia, measuring the extent to which arguments were combined in the sense of a diathesis-stress model. Participants’ answers were rated by two experts to distinguish between different levels of conceptual knowledge. An answer which contained a simple explanation (biological or social respectively) was rated with one point. Two points were assigned when participants named both biological and social causes. They received three points if they pointed out to some kind of interaction or correlation between different social and biological factors. And participants received four points if they referred to a model that postulates that external stress (social) can uncover an inherent (biological) vulnerability.
- External assimilation: For measuring external processes we made log-file analyses to compare the initial version of the wiki page to the last version at the end of the experiment. External assimilation was measured by counting the number of words inserted into the digital artifact.
- External accommodation: For measuring external accommodation we counted the number of the phrases which participants either used to refer to interaction between social and biological causes of schizophrenia or which they used to connect arguments (e.g., “on the one hand … on the other hand”, “in contrast”, “however”) in the digital artifact.

Three studies examined the hypothesis of an inverted U-shape relationship between information in the shared digital artifact and knowledge of individuals on the one hand and knowledge progress on the other, comparing processes of externalization and internalization.

Incongruity was operationalized in these studies as the difference between knowledge entities in the cognitive system and information entities in the social system. There are two possible experimental implementations: keeping constant the amount of knowledge available in the cognitive system and manipulating the amount of information in the social system or keeping constant the amount of available information in the social system and manipulating the amount of knowledge in the cognitive system. The former option was implemented in Study #1, the latter in Studies #2 and #3. Thus, in the sense of the model, Study #1 primarily varied the option for externalization and Studies #2 and #3 the options for internalization.

Study #1

Study #1 examined three experimental conditions with different degrees of incongruity between knowledge in the cognitive systems and information in the social system, keeping knowledge in the cognitive systems constant. In all three experimental conditions, all of the ten arguments were available for the participants as their own “prior knowledge”. Variation in the experimental conditions concerned the extent of information that were presented in the digital artifact: the ten arguments were used to build four different versions of the wiki page on the causes of schizophrenia, distinguishing three experimental conditions. The wiki page in the low-incongruity condition contained all the arguments; it might be described as a complete entry. Taking into account potential qualitative differences between the two positions, the medium-incongruity condition in the experiment was based on two versions of the wiki page: one version contained the four biological arguments and the other version the four social arguments. Both of these might be labeled as one-sided content. The wiki page on the causes of schizophrenia in the high-incongruity condition did not contain any content (see Figure 3).

So the emphasis in this experiment was on manipulating processes of externalization. 61 university students participated in this study. 43 of them were women, 17 men (and 1 person with undisclosed gender). The participants' mean age was 24.64 years (*SD*=10.58). They were distributed at random between the experimental conditions (Moskaliuk, Kimmerle, & Cress, 2008).

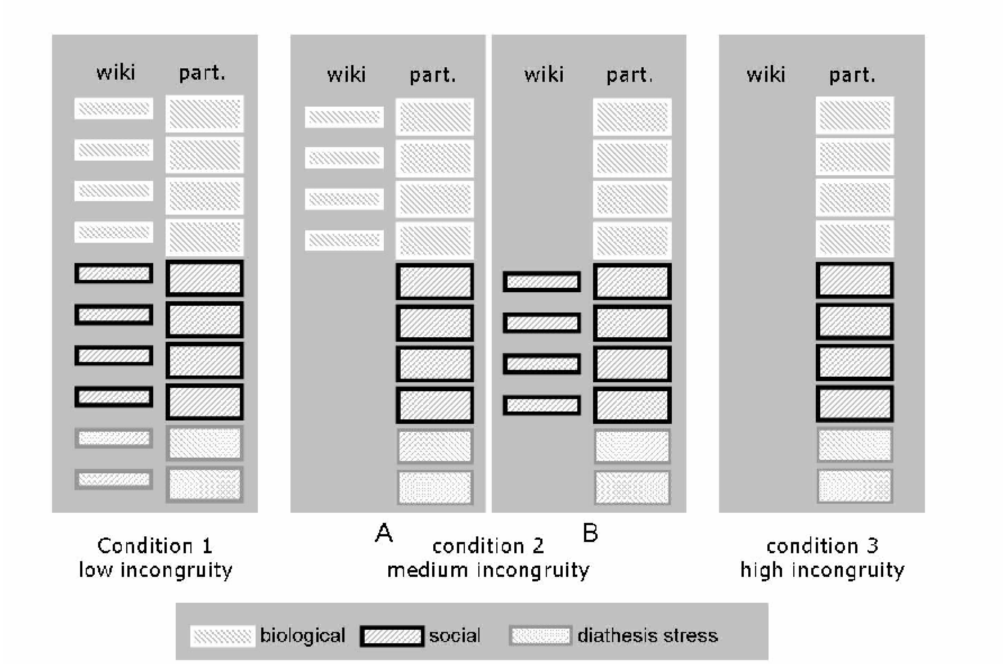

Figure 3. Distribution of information provided in the artifact and availability to participants in three experimental conditions of Study #1 (condition 2A and 2B are logically equivalent).

It was expected that medium incongruity will be most conducive to all four processes: in the medium-incongruity condition more external assimilation (Hypothesis 1), more internal assimilation (Hypothesis 2), more external accommodation (Hypothesis 3), and more internal accommodation (Hypothesis 4) were expected.

Statistical analyses of the data revealed the following results:

External assimilation. As expected (Hypothesis 1), in the medium-incongruity condition participants contributed significantly more words than in the low-incongruity condition: M_{med}=210.00 (SD=124.98) vs. M_{low}=78.78 (SD=64.17), $t(38)$=4.03, p<.01. But there was no difference between high and medium incongruity: M_{med}=210.00 (SD=124.98) vs. M_{high}=268.70 (SD=99.35), $t(40)$=-1.67, p>.05.

Internal assimilation. As expected (Hypothesis 2), the factual knowledge in the medium-incongruity condition was higher than in the low-incongruity condition: M_{med}=15.50 (SD=2.30) vs. M_{low}=13.78 (SD=2.82), $t(38)$=2.13, p=.02. Factual knowledge in the medium-incongruity condition was also higher than in the high-incongruity condition: M_{med}=15.50 (SD=2.30) vs. M_{high}=14.24 (SD=1.92), $t(41)$=1.95, p=.03.

External accommodation. As expected (Hypothesis 3), we found significantly more external accommodation in the medium-incongruity condition than in the low-incongruity condition: M_{med}=3.29 (SD=2.70) vs. M_{low}=1.78 (SD=1.70), $t(37)$=2.04, p=.02. And there was also more external accommodation in the medium-incongruity condition than in the high-incongruity condition: M_{med}=3.29 (SD=2.70) vs. M_{high}=2.05 (SD=0.94), $t(39)$=1.93, p=.03.

Internal accommodation. As expected (Hypothesis 4), the conceptual knowledge in the medium-incongruity condition was higher than in the low-incongruity condition: M_{med}=3.04 (SD=1.13) vs. M_{low}=2.29 (SD=1.16), $t(37)$=2.03, p=.02. Conceptual knowledge in the medium-incongruity condition was also higher than in the high-incongruity condition: M_{med}=3.04 (SD=1.13) vs. M_{high}=2.43 (SD=1.03), $t(41)$=1.87, p=.03.

Study #2

The second experiment was, so to speak, a mirror-inverted replica of the previous one. While in the experimental conditions of the previous study participants' prior knowledge was kept constant and the shared digital artifact differed in the information it contained, the artifact in the second experiment contained the same information in all conditions, and variation concerned the knowledge of the participants.

In all three experimental conditions, all of the arguments were presented in the digital artifact. Here, the artifact only provided the four social and the four biological arguments. Participants were not provided with the arguments on the diathesis-stress model because we wanted to examine whether they were able to find out these arguments on their own (this was considered a more valid test for the construction of conceptual knowledge). Variation in the experimental conditions concerned the extent of information that was available to participants as their own "prior knowledge" when working on the digital artifact (see Figure 4).

In condition 1 (low incongruity), the participants knew all eight arguments, in condition 3 (high incongruity) they had no prior knowledge at all. In the "medium incongruity" condition, the participants only knew the arguments of one position on causes of schizophrenia, i.e. either the four social arguments (condition 2A) or the four biological arguments (condition 2B).

In all conditions, participants had instant access to the wiki and were able to work with it while reading the newsletters. This study was carried out with 77 participants. 45 of these were women, 32 men. Their mean age was 23.55 years (*SD*=3.59). The participants were randomly assigned to one of the three experimental conditions.

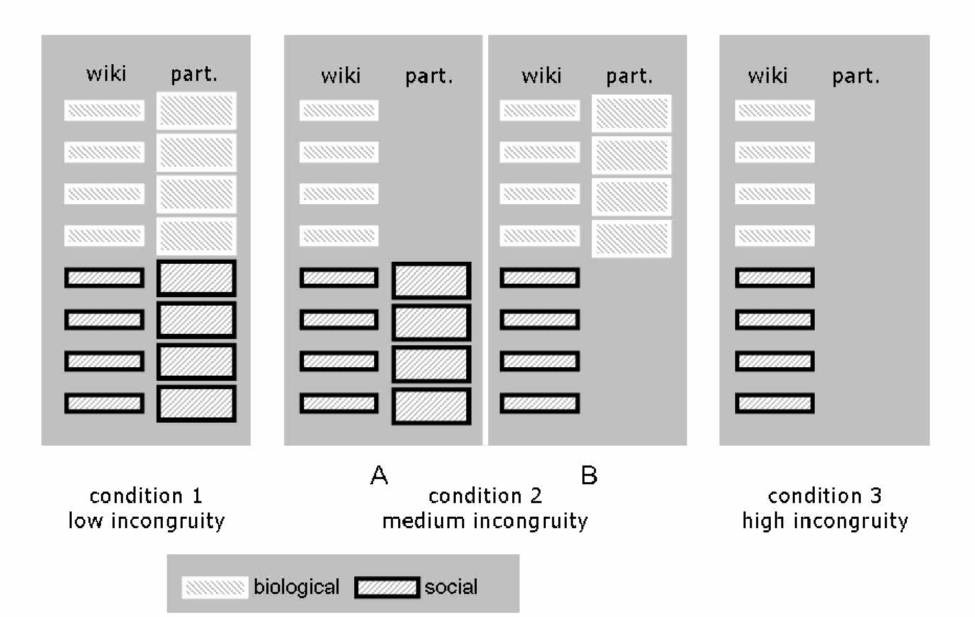

Figure 4. Distribution of information provided in the artifact and availability to participants in three experimental conditions (condition 2A and 2B are logically equivalent) in Studies #2 and #3.

The varying extent of information that was available through the newsletters provided a variable for the extent of possible internalization in the experiment. The potential for externalization was kept at a constantly low level, as the artifact contained all the relevant information. The theoretical considerations and corresponding research questions, as presented above, led to the following hypotheses:

People with little previous knowledge will find it difficult to externalize anything at all, so the lowest external assimilation was expected in condition 3 (Hypothesis 1). As the groups differ in their prior knowledge, a corresponding difference of factual knowledge was expected, which could also serve as a treatment check. It was assumed, in other words, that differences of prior knowledge continue to exist because of the lack of opportunities to externalize one's own knowledge (Hypothesis 2). The theoretical model predicted that the perceived conflict between information in the artifact and the participants' own prior knowledge was highest at medium incongruity. This should lead to more accommodation (Hypothesis 3) in the digital artifact and more distinct conceptual knowledge, as a result of internal accommodation (Hypothesis 4).

Statistical analyses of the data revealed the following results:

External assimilation. As assumed (Hypothesis 1) we found more external assimilation in the medium-incongruity condition than in the high-incongruity condition: M_{med}=64.33 (*SD*=59.65) vs. M_{high}=11.71 (*SD*=26.09), $t(49)$=3.79, p<.01. And we found more external assimilation in the low-incongruity condition than in the high-incongruity condition: M_{low}=64.28 (*SD*=58.80) vs. M_{high}=11.71 (*SD*=26.09), $t(44)$=3.79, p<.01.

Internal assimilation. As assumed (Hypothesis 2) we found more internal assimilation in the low-incongruity condition than in the medium-incongruity condition: M_{low}=13.88 (*SD*=2.38) vs. M_{med}=12.57 (*SD*=2.67), $t(52)$=1.87, p=.03. But we could not find more internal assimilation in the medium-incongruity condition than in the high-incongruity condition: M_{high}=11.82 (*SD*=3.17) vs. M_{med}=12.57 (*SD*=2.67), $t(50)$=0.92, p=.18.

External accommodation. As assumed (Hypothesis 3) we found more external accommodation in the medium-incongruity condition than in the low-incongruity condition. The data tended to support this hypothesis; this is, however, only a marginal effect: M_{med}=1.57 (*SD*=1.89) vs. M_{low}=0.96 (*SD*=0.89), $t(53)$=1.48, p=.07. And we found more external accommodation in the medium-incongruity condition than in the high-incongruity condition: M_{med}=1.57 (*SD*=1.89) vs. M_{high}=0.29 (*SD*=0.46), $t(49)$=3.04, p<.01.

Internal accommodation. Hypothesis 4 assumed that we would find more internal accommodation in the medium-incongruity condition than in the low-incongruity condition. The data did not support this hypothesis: M_{low}=1.12 (*SD*=0.38) vs. M_{med}=1.07 (*SD*=0.37), *t*(53)=0.38, *p*=.35. And we did not find more internal accommodation in the medium-incongruity condition than in the high-incongruity condition: M_{high}=1.05 (*SD*=0.58) vs. M_{med}=1.07 (*SD*=0.37), *t*(50)=0.16, *p*=.44.

This means that some of the expected effects could not be detected or were only of marginal significance. The results concerning Hypothesis 2 would indicate that the difference of knowledge of those users who participated in the study may have been too small. For that reason, a period of learning was introduced in the following study. Prior to working on the wiki, participants were asked to consider the content of the newsletter.

Study #3

This experiment corresponded to Study #2, except that an additional learning phase preceded the rest in order to obtain more significant differences of the participants' prior knowledge. The learning phase differed depending on the number of newsletters which a participant had received. In condition 1, participants had 20 minutes to consider the newsletters, in condition 2 this was 10 minutes, and in condition 3 no such learning phase was necessary because participants were meant not to acquire any prior knowledge. So, this condition is exactly the same as the high-incongruity condition in Study #2. In order to conduct the experiment efficiently, we simply re-used the data for this condition from Study #2 (i.e. did not invite any new participants for this condition). This study was carried out with 72 participants. 55 of these were women, 17 men. Their mean age was 22.06 years (*SD*=3.48).

Statistical analyses of the data revealed the following results:

Internal assimilation. As assumed (Hypothesis 1) we found more external assimilation in the medium-incongruity condition than in the high-incongruity condition: M_{med}=84.00 (*SD*=64.92) vs. M_{high}=11.71 (*SD*=26.09), *t*(44)=4.78, *p*<.01. And we found more external assimilation in the low-incongruity condition than in the high-incongruity condition: M_{low}=89.00 (*SD*=63.38) vs. M_{high}=11.71 (*SD*=26.09), *t*(43)=5.21, *p*<.01.

Internal assimilation. As assumed (Hypothesis 2) we found more internal assimilation in the low-incongruity condition than in the medium-incongruity condition: M_{low}=14.72 (*SD*=2.01) vs. M_{med}=13.68 (*SD*=2.34), *t*(48)=1.69, *p*=.05. And we could also find more internal assimilation in the medium-incongruity condition than in the high-incongruity condition: M_{high}=11.82 (*SD*=3.17) vs. M_{med}=13.68 (*SD*=2.34), *t*(45)=2.31, *p*=.01.

External accommodation. As assumed (Hypothesis 3) we found more external accommodation in the medium-incongruity condition than in the low-incongruity condition, yielding a more clear-cut effect than in Study #2: M_{med}=2.04 (*SD*=1.79) vs. M_{low}=0.58 (*SD*=0.93), *t*(44)=4.36, *p*<.01. And we found more external accommodation in the medium-incongruity condition than in the high-incongruity condition: M_{med}=2.04 (*SD*=1.79) vs. M_{high}=0.29 (*SD*=0.46), *t*(49)=3.04, *p*<.01.

Internal accommodation. Hypothesis 4 assumed that we would find more internal accommodation in the medium-incongruity condition than in the low-incongruity condition. The data tended to support this hypothesis; this is, however, only a marginal effect: M_{low}=1.20 (*SD*=0.65) vs. M_{med}=1.48 (*SD*=0.82), *t*(48)=1.34, *p*=.09. And we could also find more internal accommodation in the medium-incongruity condition than in the high-incongruity condition: M_{high}=1.05 (*SD*=0.58) vs. M_{med}=1.48 (*SD*=0.82), *t*(45)=2.07, *p*=.02.

In this study, the result that more learning time leads to more factual knowledge (Hypothesis 2) may be interpreted as a successful treatment check. What is relevant from the point of view of verifying theoretical predictions is the advantage of medium incongruity for processes of internal and external accommodation. This cannot be explained with the length of learning time, but only with incongruity between the information contained in the shared digital artifact and the participants' own knowledge.

Discussion

This article provides a survey of studies on a framework model of learning and knowledge building with shared digital artifacts. On the basis of Luhmann's systems theory the model describes processes of individual learning and collaborative knowledge building by identifying shared digital artifacts and the respective communities behind these artifacts as "social systems", and by examining the interaction between such a social system and the cognitive systems of individuals. The model refers to Piaget's theory of equilibration to illustrate cognitive development and applies the concept of assimilation and accommodation processes to the social system as well.

The article highlighted assimilation and accommodation processes in a shared digital artifact by citing real examples from the Online Encyclopedia *Wikipedia*. Co-evolution of cognitive systems and the social system was visualized by means of social network analysis. The model considers incongruity between the information in the digital artifact and people's previously existing knowledge as an important factor of people's willingness to participate in knowledge-building processes and, thus, to contribute to the development of cognitive and social systems. Experimental studies have indeed shown that this incongruity is a significant factor of collaborative knowledge building. Future research in this field should aim at identifying further influencing factors of collaborative knowledge building with social software.

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Does social software fit for all? Examining students' profiles and activities in collaborative learning mediated by social software

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Abstract: In this study the dependencies between higher education students' profiles, activities, and learning outcomes in collaborative learning -- as mediated by social software -- were examined. Although the sample size in this study was small (n=22), Bayesian Dependency Modeling method provided statistically viable insight. The results show that learners who were active reflectors in their blogs, but who were also interested in what others achieved, obtained the best results in knowledge tests. Based on the analysis, two distinct learner profiles that reflect differences in the students' dependencies can be distinguished: monitor and reflector. Furthermore, an indirect dependencies found in the analysis suggests that both reflectors and monitors are also active wiki editors and participants in face-to-face discussions. Further qualitative analyses are needed in order to get an in-depth view of the complex interactions and dependencies within and between the face-to-face and virtual, but also individual and social, planes of collaboration.

Introduction

Since Mark Weiser (1991) coined the term "ubiquitous computing", an increasing amount of attention has been given to technologies that provide support to people "on the move" (Laru & Järvelä, 2008a). At the same time, a plethora of digital and networked tools have appeared and been established on the Internet. These digital applications, which enable interaction, collaboration and sharing between users, are frequently referred to as Web 2.0 (Bridsall, 2007) or social software (Kesim and Agaoglu, 2007). The ongoing integration of social software and affordances of wireless technologies into mobile-device-based social networks has created fascinating possibilities for organizing novel learning and working situations (Järvelä, Näykki, Laru, Luokkanen, Järvelä, 2007). In spite of the tremendous popularity of the use of social software in students' free time, there are very few empirical studies which consider student activities with social software for the purpose of learning.

The general claim has been that when new technologies and software are used in an educational setting, new learning opportunities arise. Many case studies and design experiments using mobile technologies or social software for innovative pedagogical ideas and design studies have been conducted and documented (Laru & Järvelä, 2008a). However, only a few studies provide detailed arguments as to what new opportunities the software offers in terms of learning interaction and collaboration and what the exact processes are that the software addresses. We claim that it is not only the learner being "mobile" or "social" that matters. A stronger argument for applying mobile tools and social software for education is that of increasing students' opportunities for interactions and sharing ideas and thus, increasing opportunities for an active mind in multiple contexts (Dillenbourg, Järvelä, & Fischer, 2007).

In this paper, social software tools are a part of the socio-technical design for a course in a higher education context. The pedagogical ideas behind the design are grounded on collaborative learning, including the socially shared origin of cognition as well as self-regulated learning theory. Specifically, special effort has been placed on enhancing and scaffolding collaborative learning as a cognitive, social, and motivated activity.

Aim

In this study, dependencies between students' profiles, activities and learning outcomes in collaborative learning – as mediated by social software -- were examined. This paper answers the following three research questions: (1) Are differences in the learners' profiles related to differences in their learning outcomes; (2) Are the learners' actions in the Web 2.0 tools and face-to-face sessions related to their learning outcomes; and, (3) Are the learners' actions in the Web 2.0 tools and face-to-face sessions related to differences in their profiles?

Method and participants

The study participants included 22 adult students (17 females and 5 males, median age 38 years) in a higher education learning sciences and educational technology course for a period of 12 weeks (http://edufeed.wikispaces.com). Groups of 4-5 learners were established for recurrent individual and collective phases (Figure 1) which were facilitated with social software (media sharing, personal weblogs, wiki and syndication services via RSS) as well as mobile phones (media sharing, syndication) and laptop computers (Järvelä & Laru, 2008b). In addition, the students had six group reflection sessions where their task was to reflect on the content of the lectures. After the group reflection students continued their reflections in their individual blogs. In the middle and at the end of the course, the students participated in collective "meaning-making sessions" where they reviewed all the group members' weblogs and jointly constructed knowledge into their groups' wikis. The students' contributions and course-related information were also available for individual monitoring in an RSS-syndication service.

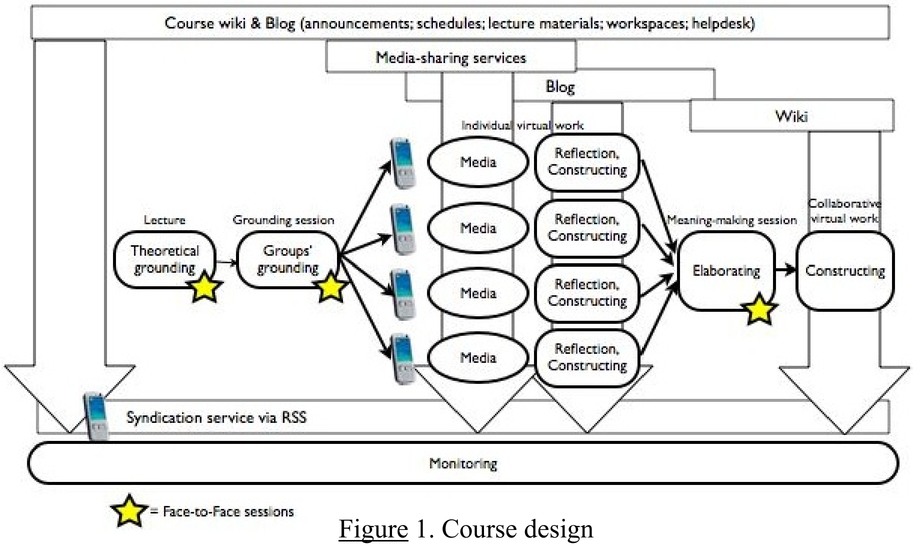

Figure 1. Course design

Instrument

All participants completed a two-part, self-report questionnaire containing 101 items. Each item asked the student how strongly he or she agreed or disagreed with a statement. Responses were based on a 7-point Likert-type scale ranging from "strongly disagree (1)" to "strongly agree (7)". The first section of the questionnaire was derived from the Motivational Regulation Strategies Questionnaire (Wolters, 2001) and contained items about students' use of five different motivational regulation strategies including self-consequating (A_SeCo), environment control (A_ECO), performance self-talk (A_PST), mastery self-talk (A_MST), and interest enhancement (A_IntEnh). The second and third sections of the questionnaire were adapted from the Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia & McKeachie, 1993). The second section contained items about students' five different motivational orientations, including intrinsic goal orientation (B_IGO), extrinsic goal orientation (B_EGO), task-value (B_TV), control of learning beliefs (B_CoLB), and self-efficacy for learning and performance (B_SeEfLe). The third section contained items about students' use of five different cognitive and metacognitive strategies including rehearsal (C_Reh), elaboration (C_Elab), organization (C_Org), critical thinking (C_CT), metacognitive self-regulation (C_MCSR), and two resource management strategies including time and study environment (C_TSE) and peer learning (C_PeLe). The theoretical structure and items of the questionnaire are reported in detail in Pintrich et al. (1993) and Wolters (2001).

Procedures

At the beginning of the course, the students were profiled with the help of the three-part self-report questionnaire. In addition, a control variable was introduced by measuring the students' initial level of knowledge (CT_Pre_sum) about the course topics using a paper-and-pencil test. After the course, students were asked to answer the test again in order to measure the level of understanding that they acquired during the course (CT_Gain). Data about the learners' face-to-face and virtual actions were collected by using video-observations, stimulated recall interviews and log-files. Log-file variables used in the analysis included factors relating to students' use of mobile phones to upload multimedia to file-sharing communities (Flickr Images, YouTube Videos), personal blogs (WP_Entries, WP_Wordcount), groups' wikis (WS_Edits, WS_Wordcount, WS_Messages_Written) and RSS-readers (RSS_Read). In addition, each learner's total participation (F2F_sum) in groups' face-to-face reflection and meaning-making sessions was calculated from the observation data.

Statistical analyses

Bayesian Dependency Modeling (BDM), which predicts the most probable statistical dependency structure between the observed variables, was used for data analysis (Myllymäki, Silander, Tirri & Uronen, 2002). Bayesian modeling allows the use of nominal (e.g., gender) and ordinal (e.g., Liker-scale) variables in the analysis and it assumes no minimum sample size for technically robust calculations. A graphical visualization of a Bayesian network (BN) has two components: (1) Observed variables visualized as ellipses; and, (2) Dependencies visualized as lines between nodes.

When interpreting the results of BDM, it is important to understand that the directed arches (i.e., arrowhead arches) are interpreted as recursive statistical relationships. The reason for this is because, in this study, controlled experiments were not conducted and there is therefore no way to be sure that relationships between observed variables are causal by nature. For example (Figure 2: Middle), variable B_TV (task-value) has an arrow pointing to CT_Gain (learning outcome), but this dependency should be read "an increasing level of task-value has a positive effect on performance in conceptual knowledge testing."

Results

Are differences in the learners' profiles related to differences in their learning outcomes?

The results showed that none of the five self-regulation factors was related to the learning outcome (Figure 2: Left). A direct causal influence between the motivational variables and learning outcomes (Figure 2: Middle) shows that self-effective (B_SeEfLe) students who were interested in the subject matter of the course (B_TV) achieved the best results in the conceptual knowledge test (CT_Gain). Furthermore, levels of extrinsic goal orientation (B_EGO) and control of learning beliefs (B_CoLB) were also related to level of knowledge acquired during the course. No dependencies were found between learning strategies and learning outcome variables (Figure 2: Right). The controlling variable (CT_PreSum) was not statistically related to learning outcome (CT_Gain). However, results show that learners with higher pre-existing knowledge in course subjects were more self-consequated (A_SeCo), had greater self-efficacy (B_SeEfLe) and task-value (B_TV), and were more self-regulative (C_MCSR) when compared with their peers.

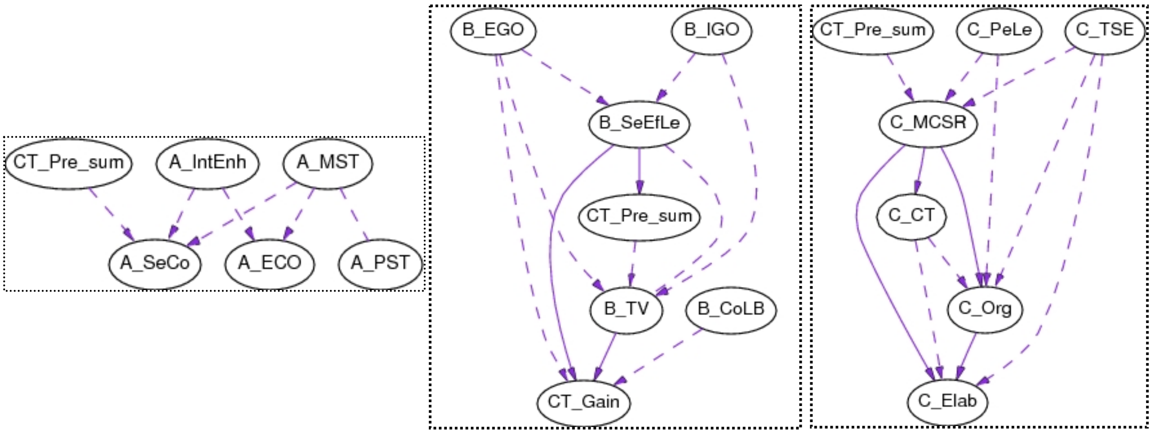

Figure 2. Left: Bayesian network of self-regulation factors (A*) and learning outcome (CT_*); Middle: Bayesian network of motivational factors (B_*) and learning outcome (CT_*); Right: Bayesian network of learning strategies factors (C_*) and learning outcome (CT_*).

Are the learners' actions in the Web 2.0 tools and face-to-face sessions related to their learning outcomes?

The second research question aimed to clarify whether the learners' actions in the Web 2.0 tools and face-to-face sessions were related to their learning outcomes (Figure 3). The relationships between two activity variables (RSS_Read; WP_Entries) and performance in the conceptual knowledge test (CT_Gain) suggests that students who actively monitored peers' contributions and reflected their own thoughts individually in blogs learned more during the course. Furthermore, six activity factors were directly related to other factors and were thus indirectly related to learning outcome. Based on these dependencies, it is clear that students who were active in following others' contributions (RSS_Read) were also active blog writers, wiki editors and face-to-face discussion participants. In addition, the controlling variable (CT_PreSum) was not statistically related to learning outcome or other variables. However, when the results of the second and third sections are connected, one relationship between latent variables and the controlling variable can be found: learners with pre-existing knowledge were more active in building knowledge (Figure 4) in their group's wiki (WS_Wordcount).

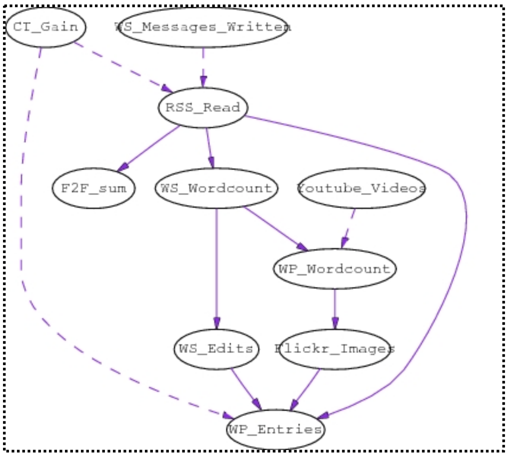

Figure 3. Bayesian network of learners' activity and learning outcome (CT_*)

Are the learners' actions in the Web 2.0 tools and face-to-face sessions related to differences in their profiles?

The third research question focused on the relationship between learners' profiles and actions in the Web 2.0 tools and face-to-face sessions. First, from the viewpoint of regulative strategies, the BN analysis (Figure 4: Left) showed that learners who were active users of syndication services (RSS_Read) reported high levels of environmental control and interest-enhancement, as well as performance self-talk as a self-regulation strategy and high levels of elaboration as learning strategy.

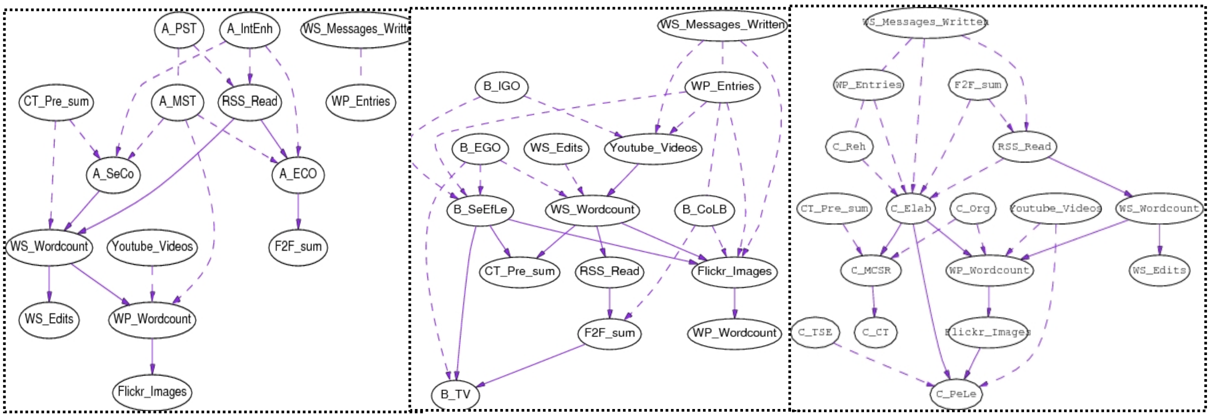

Figure 4. Left: Bayesian network of self-regulation factors (A_*) and learners' activity; Middle: Bayesian network of motivational factors (B_*) and learners' activity; Right: Bayesian network of learning strategies factors (C_*) and learners' activity

Second, the BN analysis from the perspective of motivational factors (Figure 4: Middle) showed that only two motivational factors -- self-efficacy for learning (B_SeEfLe) and control of learning beliefs (B_CoLB) -- were directly related to the active use of blogging tools (WP_Entries) and none was directly related to the active use of syndication services (RSS_Read). Results showed that learners with higher pre-existing knowledge of course subjects were more self-consequated (A_SeCo), had greater self-efficacy (B_SeEfLe), and task-value (B_TV), and were more self-regulative (C_MCSR) when compared to their peers.

Third, from the standpoint of learning strategies (Figure 4: Right) the study reveals that active monitoring of others' activities (RSS_Read) and reflecting in a personal journal (WP_Entries) were related to elaboration (C_Elab). The latter was also related to rehearsal as a learning strategy. Furthermore, BN modeling reveals that the elaboration factor was directly related to many individual and collective activities, including learners' individual reflections in their blogs (WP_Entries, WP_Wordcount), monitoring others (RSS_Read), and groups' reflections in the face-to-face sessions (F2F_Sum). The elaboration factor was also related to peer-learning (C_PeLe), rehearsal (C_Reh) and metacognitive self-regulation factors.

However, results show that learners with higher pre-existing knowledge of course subjects (CT_Pre_sum) had greater self-consequation (A_SeCo) and self-efficacy (B_SeEfLe) than learners who used more metacognitive self-regulation skills for learning (C_MCSR). Yet, results show that they were more active in building knowledge in their group's wiki (WS_Wordcount).

Conclusions

In this study, the relationships between learning outcomes, actions and motivations, learning strategies and regulation profiles were explored in an off-the-self social networking environment with an empirical sample of 22 adult learners of a university-level educational technology course.

The results showed that students who were interested in the subject matter of the course, were self-effective learners, able to control their learning beliefs, and who had an extrinsic goal orientation, achieved the best results in the conceptual knowledge test. An analysis of the dependencies between learning outcome and learners' activities revealed that learners who were active reflectors in their blogs, but also interested in what others achieved, had the best results in the knowledge test. Based on the analysis, two distinct learner profiles can be distinguished based on differences in students' dependencies: monitor and reflector. Monitors are active users of syndication services with high levels of environmental control and interest-enhancement, performance self-talk as a self-regulation strategy, and elaboration as learning strategy. Reflectors are active bloggers who reported high levels of control of learning beliefs, self-effectiveness as motivational orientations, and elaboration and rehearsal as their learning strategies. Indirect dependencies between activity variables and learning outcomes suggest that both reflectors and monitors were also active wiki editors and participants in the face-to-face discussions. However, analyses of the role of the controlling variable in the data show that learners with pre-existing knowledge were (for example) more confident about subjects taught in a course, valued the course more, and had better self-regulation skills than peers. Yet, learners with pre-existing knowledge affected the collaborative nature of activities by being active in building knowledge collaboratively in their group's wiki.

Further qualitative analyses are needed in order to derive an in-depth understanding of these complex interactions and dependencies – not only within and between face-to-face and virtual interactions, but also individual and social planes of collaboration. In order to address this interest, the next step is to focus on conducting a qualitative analysis following the guidelines of "eclectic analysis" established by Suthers et al. (2007).

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PART IV

DESIGNING FOR CSCL PRACTICES

Adaptation Patterns in Systems for Scripted Collaboration

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Abstract: This work presents a prototype method (DeACS) for identifying useful adaptation patterns to be embedded in systems for adaptive collaboration scripting. Collaboration scripts are didactic scenarios that guide and support the collaborative learning activity while adaptive collaboration scripting is the idea that computer-supported collaboration scripts can be adapted during run time, to provide learning experiences tailored to individual and group characteristics. An adaptation pattern is described as a well-defined adaptation process that can be initiated by the system when specific conditions are identified during script implementation. In order to model the proposed method twelve postgraduate students were engaged in a pyramid-type collaboration script and the analysis of the learning experience provided the basis for identifying a number of possible adaptation patterns. The paper discusses also next steps for advancing the design and evaluation of adaptation patterns in systems for scripted collaboration.

Introduction

Collaborative learning is important for students both for social and cognitive reasons (Dimitracopoulou & Petrou, 2003). However collaborating students might fail to engage in productive learning interactions when left without teachers' support (Hewitt, 2005). Scripted collaboration is the idea that collaboration can be guided by didactic scenarios, aiming to engage students in fruitful learning interactions. Lately there have been efforts for the formalization of collaboration scripts (Kobbe et al., 2007) and the development of computer-based environments to support scripted collaboration (e.g. Bote-Lorenzo, Gomez, Dimitriadis, Asensio, & Jorrin, 2008).

Nevertheless, adjusting the script level of granularity and flexibility emerges as an important issue that affects the outcome of scripted collaboration (Dillenbourg & Tchounikine, 2007). Although a teacher can be flexible enough and adjust various collaboration parameters during script run-time, CSCL systems for scripted collaboration are far from exhibiting a comparable level of flexibility. We have argued elsewhere (Demetriadis & Karakostas, 2008; Karakostas & Demetriadis, 2008) that a possible solution to the script flexibility issue could be the integration of adaptive characteristics to systems for scripted collaboration. "Adaptive collaboration scripting" is, in general, the idea that computer–based environments for scripted collaboration can operate in an adaptive mode in order to significantly improve the learning conditions. Based on the Adaptive Educational Systems (AES) and the Computer-Supported Collaborative Learning systems (CSCL systems), adaptive scripting tailors the learning experience to the needs and characteristics of the individual learner or teams and implements the beneficial adjustments during the specific learning situations emerging from script implementation.

In this work we present a prototype method for identifying possible adaptation patterns within the context of a collaboration script. An adaptation pattern is described as an adaptation process that can be initiated by the system when specific conditions are met during script runtime. The objective is to enhance the flexibility of script implementation and offer adaptive support to students based on their personal and/or group profile. In order to model the proposed method twelve postgraduate students were engaged in a pyramid-type collaboration script and the analysis of the learning experience provided the basis for identifying a number of possible adaptation patterns. In the following, after concisely presenting a conceptual framework for adaptive collaboration scripting, the paper focuses on the implementation of the method and identification of adaptation patterns. Next steps for advancing the design and evaluation of adaptation patterns in systems for scripted collaboration are also discussed.

Background

Scripted Collaboration: Promises and Pitfalls

Researchers have systematically emphasized that collaborating students might fail to engage in productive learning interactions when left without teachers' consistent support and scaffolding (Hewitt, 2005). It has been suggested that the instructor guides the learners' interactions within the group, by implementing an appropriate collaboration script (Kobbe et al., 2007). Collaboration scripts are didactic scenarios that aim to structure and guide the collaborative learning process by specifying the way in which learners interact with one another. Every script can be seen as a sequence of phases with five major attributes each: (a) the kind of task that has to be performed, (b) the composition of the group, (c) the task distribution (among group members), (d) interaction and communication mode, and (e) script's time duration (Kobbe et al., 2007). Scripts can also be distinguished in (a) macro-scripts focused on the organization and the structure of the collaborative activity, and (b) micro-scripts focusing on a more psychological perspective, providing support to individuals for specific activities in order to enhance their socio-cognitive skills (Dillenbourg & Tchounikine, 2007). Furthermore, CSCL scripts are computer-based representations of collaboration scripts where the role of the computer is to provide participants with communication tools and manage script's time and information flows (Tchounikine, 2008).

Implementing CSCL scripts has been reported to result in improved learning outcomes (e.g. Rummel & Spada, 2007; Weinberger, Fischer, & Mandl, 2002). However, CSCL scripting has been criticized for its loss of flexibility (difficulty of modifying a script in run time according to the needs of the instructional situation) (Dillenbourg & Tchounikine, 2007), and also the danger of "over-scripting" collaborative activity (the pitfall of overemphasizing script imposed interactions and constraining natural collaboration) (Dillenbourg, 2002).

Adaptive Collaboration Scripting: Maximizing the Script Benefits

Against this background, we argue that adaptive scripting techniques can be beneficial for learners when embedded in CSCL scripting systems. Such systems could adaptively tailor the learning experience to the needs and characteristics of both the individual learner and the group so that the benefits from the scripted collaboration are maximized. We call such systems "Adaptive Collaboration Scripting systems" or ACS systems and, in general, we suggest that the adaptation methods in ACS systems focus on two major objectives: (a) *enhance peer interaction*: the implementation of user modelling techniques and respective adaptation rules, when appropriate, can help establish conditions of more effective peer interactions (e.g. when recording learners' profile during group formation process to create hetero- or homogenous groups) and (b) *establish conditions of flexible scripting*: adjusting the level of scripting to avoid conditions of over- or under-scripting considering the learners' and/or the groups' needs and characteristics.

Efforts to implement adaptive techniques in CSCL in order to improve the learning experience have already been reported to the literature. For example, Harrer, Malzahn, and Wichmann (2008) combine aspects from CSCL, pedagogical design, and Intelligent Tutoring Systems (ITS) to provide an integrated architecture for supporting collaborative learning activities. Our point of view, however, is to emphasize the need for a generalized conceptual framework of adaptive scripting, considering not only the learner's (or group's) characteristics but also the specific characteristics of the implemented script.

Designing an Adaptive Collaboration Scripting System

Basics of an ACS system

An ACS system should satisfy three major criteria: (a) it is a CSCL system, that is, it somehow supports collaborating groups of students; (b) it includes a user model (learner's cognitive characteristics and preferences), a group model (data relevant to the synthesis and the dynamics of the group) and a script model (computer-based script representation comprising information on specific script characteristics); (c) based on these models, it adapts the representation of the CSCL script by initiating some adaptation pattern when necessary. An adaptation pattern is a process that by taking into account the user, group and script models, aims to adjust the collaboration activity in order to maximize student engagement, satisfaction and, consequently, learning outcomes. For an adaptation pattern at least three issues should be defined: (a) conditions of initiation, (b) aspects of script to be adapted, and (c) processes to be executed.

However we maintain that not any script feature can be candidate for adaptation. The script "intrinsic" constraints (Dillenbourg & Tchounikine, 2007), that is, the core features that give to the script its specific pedagogical character and value, should not be adapted in any way. Only "extrinsic" constraints can be adapted in order to enhance scripted flexibility. Extrinsic constraints can be considered as belonging to either of two categories: (a) "Non-pedagogical", that is constraints without any pedagogical relevance. These can be altered by the teacher and/or the students simply to make the script to better accommodate the conditions of the specific implementation (for example, extending the duration of a phase because of a learner's temporal inability to meet a deadline). (b) "Pedagogical" constraints that can (should) be adapted in order to provide a well suited learning experience (for example, increasing the level of support when diagnosing learners' misconceptions). From this perspective therefore, computerized script representations should clearly define intrinsic and extrinsic (also pedagogical and non-pedagogical) script features, and adaptation patterns should affect only those features characterized as extrinsic.

The DeACS method

Overall the goal of the DeACS method (*De*signing *ACS* systems) is to provide guidance for teachers and designers on how to identify useful adaptation patterns emerging in the context of scripted collaboration, of which a computerized form can presumably be embedded in an ACS system. Developing an ACS system can be a complex process if one wishes to define beforehand and embed in the system all possible adaptation patterns that might occur during script runtime. Furthermore it is difficult to predict if these adaptation patterns would be beneficial for learners when enacted in a specific script implementation. To tackle this issue the DeACS method proposes to implement a number of iterations of the script with a twofold objective: first, to implement and evaluate a certain number of adaptation patterns that the teacher might consider as necessary for the collaborating students (based on the literature or his/her prior teaching experience), and, second, to identify possible helpful adaptation patterns emerging from the expressed needs of students during the scripted collaboration.

Generally the DeACS method proposes three major processes: (a) a top-down process: integration of selected adaptation patterns in the ideal script (the form of the script that the teacher initially wishes to put into practice) based on particular activation conditions, (b) a bottom-up process: identification of adaptation patterns that emerge from students' needs for help, support, adjustments, etc. during script runtime, (c) an evaluation process aiming to assess the added value of the adaptation patterns in the previous two categories. If the evaluation of patterns reveals beneficial impact on student learning then these patterns can become part of the script representation embedded to the ACS system.

Method Implementation in a Pyramid Script

In order to model the DeACS method twelve postgraduate students were engaged in a case-based learning (CBL) pyramid-type collaboration script for two weeks. Generally in a pyramid-type learning each participant works first individually studying any learning material and then participates in a workgroup of a gradually increasing size, to collaboratively process the material from a certain perspective. The objective of our "pyramid" script is to help students develop a satisfactory conceptual understanding of a complex domain by collaboratively analysing relevant cases. In this implementation we used the Moodle LMS to support students from distance and provide an asynchronous discussion board for them to collaborate. The CBL pyramid script had four main and one pre-scripting phase.

Pre-scripting phase: In this phase we identified a number of users' characteristics, administering appropriate questionnaires. The objective was to record (a) the students' experience with CSCL systems and the CBL method, and (b) the students' prior knowledge about the technology-supported pedagogical innovations in secondary education, which was the domain of instruction. The participants' answers showed that two of them were experienced, eight of them had little prior experience and two of them had no experience at all as teacher or learner using CSCL activities and systems. Regarding domain knowledge, three students could be characterized as experts, two had advanced knowledge, and seven of them were novices. We used this information to form the six groups in the second phase of the script and also to assign group moderators in the third phase.

1. Individual study phase (three days): In this phase each student selected and studied two case studies from an online case study database (SITES: M2, 2008) and wrote a report analyzing the cases that he/she had studied.

2. Small group synthesis phase (five days): In this phase, six groups of two were formed (three were heterogeneous and three were homogeneous according to students' prior domain knowledge). The group members discussed the cases that have studied in the first phase in order to expand and also deepen their perspective in the domain and they also submitted a deliverable (answers to a series of questions) recording their common understanding. The group collaboration implemented a "reciprocal contribution" approach: the first group member (acting as "rapporteur") suggested an answer to a question posed by the instructor while the other member (acting as a "reviewer") commented afterwards on the answer. Thus the two students reached a final common answer and they moved on to answer the next question in the list (their roles were changed).

3. Expanded group synthesis phase (five days): In this phase two larger groups of six were formed. Each large group included one member of each small group (dyad) of the second phase. New material was offered to the groups and the task was to discuss asynchronously this new material (question prompts were given) and provide their own proposal on how they would apply technology-supported innovations in secondary education. Two of the more advanced students (one for each larger group) were assigned to be moderators during group asynchronous discussion.

4. Debriefing phase: The debriefing phase was conducted in the classroom. The instructor led the discussion making comments about the quality of the deliverables and of the group collaboration.

After the end of the activity, we organized semi-structured interviews with all participating students in order to evaluate the impact of the pre-selected adaptation patterns (top-down process) and also identify possible adaptation patterns emerging from learners' needs during script implementation (bottom-up process). The content analysis of interviews transcriptions indicated both benefits and drawbacks regarding the implemented adaptation patterns and also the need for two specific new adaptation patterns. In the following we analyze in detail three of the major adaptation patterns (one embedded, two emerged).

Adaptation Patterns Analysis

Pattern 1

Name: Group Heterogeneity based on Prior Domain Knowledge
Key-idea: Formation of heterogeneous groups based on partners' prior domain knowledge is expected to foster improved collaborative learning conditions.
Activation conditions: When students need to work in groups to broaden their understanding in a domain.
Action: Form heterogeneous groups regarding students' prior domain knowledge. Heterogeneous groups should comprise learners whose prior domain knowledge should not be extremely unequal (Wang, Lin, & Sun, 2007).
Specific Implementation and Results: This is a previously known idea for group formation, embedded to the script. Therefore, this pattern implementation is considered as a top-down process. In our activity three heterogeneous groups were formed with one participant expert and one participant novice each. The rest of the groups were homogeneous (two groups with novice participants and one group with medium knowledge participants). Evaluation data, based on students' interviews, showed that two of the three heterogeneous groups had fruitful interactions and their members considered the whole phase as very efficient for them. An expert user mentioned: "*…it was very interesting and useful to see how my partner was thinking…*". The third heterogeneous group showed very inefficient communication, however, we have reasons to believe that this was for reasons unrelated to the group formation process. By contrast, in the three homogeneous groups at least one member in each group believed that the activity was not beneficial for them at all. Overall, our evaluation confirmed that what was initially perceived as helpful adaptation (i.e. forming heterogeneous groups) was indeed beneficial for students (at least for the majority of them) during the collaboration activity.
System Prerequisites: An ACS system that will support this pattern should consist of: (a) an instrument to record prior domain knowledge, (b) a module to form groups based on the principle of heterogeneity.

Pattern 2

Name: Lack of Confidence
Key-idea: Support the novice learners in larger groups in order to be more confident to participate.
Activation Conditions: Whenever a domain novice learner participates in an extended group (more than three teammates).
Action: Provide the novice learners with extra support (adaptive scaffolding) in order to motivate them and improve the quality of their contributions. A possible action is to assign specific roles to novice learners in order to make their participation in larger groups more clear and understandable.
Specific Implementation and Results: This adaptation pattern emerged during the script runtime and, therefore, it refers to the bottom-up process of the DeACS method. During script implementation we observed that the novice learners' participation in the third phase of the script was very low (as opposed to other participants). The novice learners mentioned that this phase was rather complicated for them and, also, that they were not sure how correct their opinions and thoughts were. As a result they preferred most of the time not to actively participate but rather passively attend what other group members contributed. By contrast, expert learners evaluated the third phase as the most beneficial for them (both socially and cognitively) exhibiting high participation and quality of contributions.
System Prerequisites: A system that supports the "lack of confidence" pattern should include a repository with supportive material to be presented to novice learners. For example, guidelines on how to contribute, further explanations to better understand their role during the script phase or other relevant roles to be assigned to the novice participants.

Pattern 3

Name: Advance the Advanced
Key-idea: Adjust the level of script challenge for the sole expert participant in a group in order to offer an interesting learning experience to him/her too.
Activation Conditions: A group (regardless of the number of the members) has one and only expert.
Action: Provide the domain expert participants with extra and advanced domain learning material and/or activities.
Specific Implementation and Results: During the implementation of the script we observed (bottom-up process) that the second phase of the script was not adequately challenging for the advanced learners. The three domain experts in the three heterogeneous groups mentioned that although the collaboration procedure was socially beneficial, it did not add anything new to what they already knew about the domain. It seems that for the sole advanced learner in a group, the lack of same level teammates minimizes the opportunity for interesting interaction and exchange of ideas. A possible adaptation pattern to cope with this situation would be to provide advanced learners with additional and more challenging material and/or activities.

System Prerequisites: A system implementing the "advance the advanced" pattern should include some type of repository with advanced learning material and activities.

Conclusions and Future Work

In this work we presented (a) an introductory conceptual framework for adaptive collaboration scripting and (b) a prototype method (DeACS) for identifying and evaluating the impact of adaptation patterns to be embedded in CSCL systems for adaptive scripting. In order to model the proposed method twelve postgraduate students were engaged in a pyramid-type collaboration script and the analysis of the learning experience provided the basis for identifying a number of possible adaptation patterns. This work analyzed some of these patterns that emerged both from a "top-down" and a "bottom-up" strategy, specifying the characteristics that a system should have to support this type of adaptations.

We are currently working on implementing specific adaptation patterns in a CSCL system for supporting students in scripted collaboration. Our goal is first, to explore the important technical issues related to the implementation of adaptation patterns in existing CSCL systems, and second, to examine the impact of these patterns on student learning when applied in larger scale and in an automated runtime mode.

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Over-computing CSCL Macro scripts? Gaining flexibility by using WikiPlus instead of specialized tools for authoring macro scripts

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Abstract: In this paper we show how teachers can improve collaborative learning by designing and implementing macro scripts and by regulating script sessions using enhanced wikis, called WikiPlus. To achieve optimal collaborative learning it is important to have a well designed script (preparation phase). It is also very important to being able to regulate learners' activities, because some activities can not be predicted in complex pedagogical scenarios as collaborative learning (regulation phase). WikiPlus helps enhancing the collaboration process by enabling the teacher to adapt the script whenever non predicted learner's activities happen. A prototype has been implemented, the impact of different regulation mechanisms on collaboration is discussed and wishes for macro script authoring tools of the future are formulated.

Scripts, didactic structures of collaborative learning

Scripts

Scripts have been widely discussed in the field of Computer Supported Collaborative Learning (CSCL). We present some common definitions we base our paper on:

> A collaborative script is a pedagogical scenario that learners have to follow when they are engaged in a collaborative learning setting. A script structures the collaboration process by guiding students' activities as building groups, guiding argumentation processes, visualizing ongoing work, and so on. Some of these activities are computer-based, some are not (Dillenbourg, 2002)
>
> The main idea of collaboration scripts is to prompt cognitive and social processes by participants that might otherwise not occur, thus enforcing a fruitfully structured interaction, and consequently improving the joint problem-solving and knowledge acquisition (Rummel, 2006).

In a wide area of CSCL research scripts are implemented in combination with a semi structured computer interface. The computer interface helps organizing learner's communication and collaboration, helps keeping control of the script and is the main source for research data.

Micro- Macro- Meta and other -scripts

The scientific CSCL community differentiates two kinds of scripts:

> *Micro scripts* are dialogue models, mostly argumentation models, which are embedded in the environment and which students are expected to adopt and progressively internalize. For instance, a micro-script may prompt a student to respond to the argument of a fellow student with a counter-argument (Weinberger et al., 2002).
>
> *Macro scripts* are pedagogical models, i.e. they model a sequence of activities to be performed by groups. (Dillenbourg & Hong, 2008a)

Meta scripting means showing the scripting strategy to the learners (visibility). Meta scripting may include integrating students in the scripting design process (Notari & Döbeli Honegger, 2007b).

Dillenbourg and Hong differentiate three different operationalization layers of macro scripts (Dillenbourg & Hong, 2008a). A *script instance* is a *script class* with a specific subject and content. If this script instance is carried out by specific students it is called a *script session*.

Manyscripts, a macro scripts implementation

What is Manyscripts?

Dillenbourg and Hong define their platform Manyscripts as follows:

> Manyscripts is a web-based environment where teachers may prepare the script they want to use with their students. Later on, the student will login Manyscripts to do the different activities that compose the script. It is similar to a learning management system such as Moodle, but focused on a few pedagogical methods called scripts (Dillenbourg & Hong, 2008b).

Up to now the following macro script classes have been implemented in Manyscripts: 'ArgueGraph', ConceptGrid' and WiSim (Dillenbourg and Hong, 2008b). The focus of 'ArgueGraph is on group-building strategies and the guiding of the communication among learners, ConceptGrid is a Jigsaw-like scenario (Jigsaw: Aronson et. al, 1978) trying to guide the process of knowledge distribution and among the learning group. WiSim increases collaborative effort by distributing simulation inputs across different phones and hence requiring students to negotiate values and coordinate their experimental design.

Properties of Manyscripts

Manyscripts:

- sustains implementation of three different macro scripts (ArgueGraph, ConceptGrid and WiSim) within the same environment
- can easily be implemented (using shibboleth as standard) in many university computer-networks
- has a certain didactical flexibility (group -size management like dropout of a learner within a group)
- is still quite complex to be managed by a teacher (see also: implementation of scripting sessions)
- can not be used for other types of macro scripts
- does not allow a flexible handling of activities when the learning process is ongoing.

Macro script implementation with WikiPlus

Potentials of wikis in education

Wikis are the simplest form of content management systems, invented by Ward Cunningham in 1995 (Leuf & Cunningham, 2001). It didn't take long until their potential for education was discovered (see for example: Guzdial, 2001). A definition of a wiki could be:

> A wiki is a web server with revision control on the internet, where everybody can create, change and link WebPages without additional tools and without HTML-knowledge (Döbeli Honegger, 2007).

Taking this definition we can describe some of the potentials of wikis in education:

- *create:* creating content activates and motivates students, two important prerequisites for learning
- *change:* wikis (as every computer based editor) ease the modification of content. This allows enhancing the number of revisions required by the students.
- *link:* wikis (as every hypertext system) allows links between different parts of a text. This requires that students read and understand the parts they want to link and find fitting relations. This enhances deep understanding of the topic.
- *everybody:* wikis ease collaborative content creation and therefore ease working in groups.
- *revision control:* The revision control of wikis not only lowers the danger and damage of vandalism, the revision control can also be used to track the creation process by the teacher and the students.

Three properties of wikis ease their use in education:

- *on the internet:* As wikis can be hosted on a server in the internet, schools don't have to install hardware in their own buildings and the wiki is reachable from everywhere
- *without HTML-knowledge:* using a modern wiki is as easy as using a text processor.
- *without additional tools:* As wikis only need a web browser as a tool, there is no need for software installation on the computers of the learners. This lowers the barriers for using wikis as a learning tool.

WikiPlus

By design, wikis are initially unstructured. Users have to build their own structures on page level as well as on site level. Theoretically all content in a wiki is generated manually by users, there are no automatisms or predefined structures. Nevertheless, most wikis have built in functions for dynamic content generation. We differentiate five levels of dynamic content generation in wikis and call a wiki with levels III to V a WikiPlus.

- *Special pages (Level I):* Every wiki has some special pages where existing content of the wiki is aggregated in some way or another. Recent changes, Page Index and Usage Statistics are wide spread examples of such automatic aggregation pages.
- *Built-in functions (Level II):* The next two levels of dynamic content generation offered by some wiki engines are functions which can be placed anywhere on a wikipage. The most prominent example of such a function is a dynamically generated table of contents of a wiki page.
- *Built-in-Functions with parameters (Level III):* Parameters rise the level of freedom of built-in functions. They allow filtering, sorting, and formatting the results of functions. As an important example, the wiki engine TWiki (http://twiki.org/) allows the dynamic inclusion of search results into wiki pages. These features lead to content aggregation and the dynamic generation of semi-structured content.
- *Plugins (Level IV):* Some wiki engines can be extended by plugins which allow the dynamic generation of content. Example: A plugin for generation of graphs with data saved on wiki pages.
- *Integrated programming language (Level V):* The highest level of dynamic content generation is reached by providing an integrated programming language which can access and manipulate the content of the wiki. This idea has been discussed in the wiki community for a long time (see: http://c2.com/cgi/wiki?ProgrammingInWiki and http://c2.com/cgi/wiki?WikiWithProgrammableContent). Well known examples of such wiki engines are Swiki (http://wiki.squeak.org/swiki/) which allows the embedding of SmallTalk code and FlexWiki (Bleske 2006) which uses a proprietary programming language WikiTalk.

These levels can also be read as a temporal tendency from static content to dynamic content. First wikis allowed the easy generation of static content for non-technicians. Future wiki-like sytems allow the easy definition of processes for non-technicians. This evolution makes WikiPlus a suitable tool for supporting macro scripts.

WikiPlus as a flexible macro-scripting engine for teachers

To use WikiPlus as a flexible macro-scripting engine the steps showed in table 1 are required.

Table 1: steps to set up a macro script using Wiki plus

Level	Who	Actions necessary
script class	IT professional	defining the structure and workflow by building template pages and writing default instructions for the teacher and the students
script instance	teacher	taking a script class template and instantiating it with specific content and modifying parameters and instructions where needed
script session	teacher & students	executing the script

With WikiPlus an IT professional is only needed for the implementation of a new script class. The instantiation or execution of a script can be done by teachers and students. WikiPlus allows rapid prototyping new script classes. Most features needed for implementing a script class are available in a WikiPlus. With WikiPlus it is possible to:

- support group building process
- structure the workflow and the content given by the teacher and produced by students in a script session
- monitor the activities**:**
    - by normal wiki functions like version control, recent changes or user authentication
    - by special aggregation functions provided by WikiPlus level three.

While WikiPlus has almost the same potential as specialized script engines like Manyscripts in the design phase, the big advantage of WikiPlus is the flexibility in the regulation phase. WikiPlus allows a teacher to change or enrich a running script session without programming skills or the necessity to ask an IT professional.

Prototype of ConceptGrid with WikiPlus

In the following chapter we present a possible script session of a ConceptGrid macro scripts implemented with WikiPlus. Main goal of the script session is to learn more about the concepts of semantic information structures. Students read scientific publications of researchers in the field of semantic web and information architecture. After the lecture they have to define the different key concepts and compare the different concepts. the Script design of the ConceptGrid is shown with a Didactic Process Map (see: figure 1.).

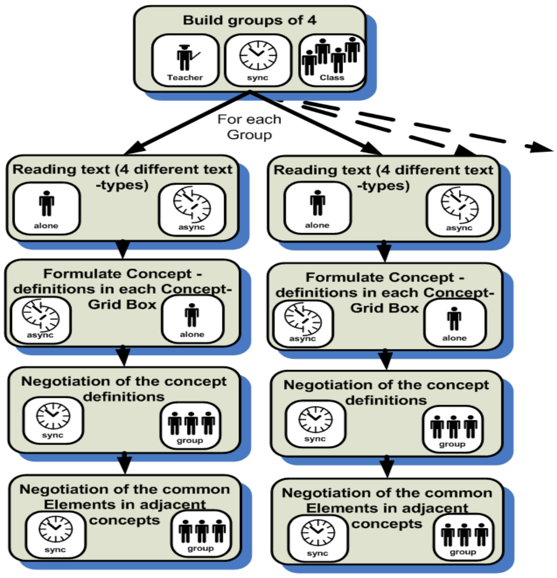

Figure 1. Visualization of the phases of a 'ConceptGrid macro script' Didactic-Process-Map-Language (Notari & Döbeli Honegger, 2007a)

A ConceptGrid class prototype implementation with TWiki

We implemented a prototype template of the ConceptGrid class with the WikiPlus engine TWiki. The TWiki can host several separate wiki spaces (called *web)* sharing the same user registrations and overall definitions. The ConceptGrid class is implemented as a *template web.* An instance of the ConceptGrid class is made by creating a new web using the ConceptGrid web as a template (see figure 2).

Figure 2. Creation of a new macro script instance ConceptGrid by copying the existing template web.

The teacher now has to configure the script instance by adding the specific content (papers to read), modifying or enhancing explanations and setting certain parameters. He does this on a special wiki page (see figure 3) where the necessary steps are explained and highlighted with a special color for teacher explanations. In our example the 16 concepts, the number of students per group and all explanations for students are defined on this single page. These parameters will automatically be used in all script sessions derived from the script instance defined.

We are convinced that it is possible to reach most of the administrative facilitations of a special macro script authoring tool (like Manyscripts) with WikiPlus while retaining almost the flexibility of a wiki (level one).

Conclusions

The holy quest of Computer Supported Collaborative Learning (CSCL) is to establish environments that directly or indirectly favor the emergence of rich and intensive interactions. Rich interactions happen especially whenever learners are engaged in argumentation, when elaborated explanations emerge, the negotiation of meanings happen and the mutual regulation of cognitive processes takes place (Dillenbourg & Hong 2008). Effective Scripting leads to maximizing these rich interactions. Existing macro script processing tools like manyscripts and others are conceived for the *designing process* of one or few specific types of macro script instances and script sessions. The potential of macro scripting tools can be enhanced by a better adaptability and flexibility. WikiPlus offers flexibility and adaptability of macro scripts for the design and the implementation of scripts. It even offers the opportunity to regulate and change student activities during the ongoing learning session. All these features can be implemented and used by teachers or even learners without the need of coding skills. Future developments of macro scripting tools should enhance design and regulation ergonomy. We propose to develop some monitoring tools to show rich and intensive interactions of the learners in order to being able to react quickly and adopt the script session. Using WikiPlus reduces the danger of over-computing by giving more possibilities to interact with design and activity of macro scripts compared to existing macro script authoring tools.

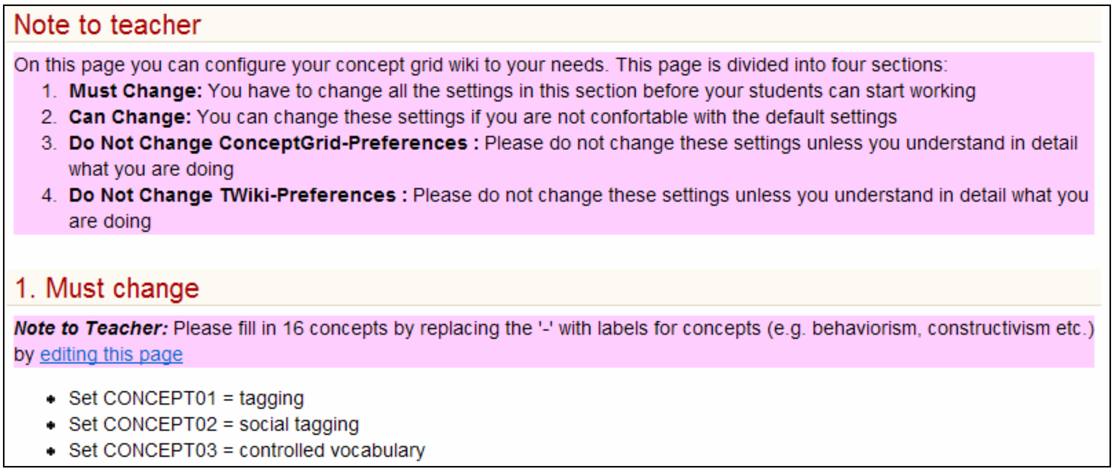

Figure 3. Creation of a new macro script instance ConceptGrid by copying the existing template web.

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Analyzing the Role of Students' Self-Organization in a Case of Scripted Collaboration

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Abstract: This work analyzes a case of computer-supported scripted collaboration, focusing on how students' self-organization affected the actual collaboration script during script run-time. Two groups of students studied learning material using a web environment designed for supporting case-based learning. The first group followed a non-scaffolded individual mode of study while students in the second group were guided by a collaboration script to work (in dyads) on the case material. Statistical analysis indicated no significant differences in the learning outcomes of the two groups. Qualitative analysis (based on students' interviews and field observations) revealed that students' self-organization resulted to a broad range of actual script implementation ranging from full conformance to partial violation of the script guidelines. The paper discusses the socio-cognitive role of students' self-organization during scripted collaboration and presents suggestions for the teacher and CSCL designer in order to enhance the engagement of collaborating students to productive learning interactions.

Introduction

Computer-supported collaborative learning (CSCL) has drawn much attention as a teaching/learning approach and is frequently implemented at all levels of education (Dimitracopoulou & Petrou, 2005). However, researchers have repeatedly emphasized that collaborating students may fail to engage in productive learning interactions when left without teachers' consistent support and scaffolding (e.g., Dillenbourg, 2002; Barron, 2003). To increase the probability that team partners will collaborate efficiently it has been suggested to guide the activity using "collaboration scripts" (e.g., O'Donnell & Dansereau, 1992; Weinberger, 2003). A collaboration script is a teacher-provided didactic scenario designed to engage a team of students in essential knowledge-generating interactions by providing guidelines on how to organize the collaborative learning activity. A computer-supported collaboration script is, accordingly, a computerized representation of a collaboration script (e.g., Kollar, Fischer & Hesse, 2006) and "scripted collaboration" is the practice of actually implementing a collaboration script to have students work within the scaffolding framework provided by the teacher.

Nevertheless, guiding collaborating students with a script is not a straightforward process. A script, typically, is conceived by an instructor as a helpful tool that will engage the team of students in meaningful learning. However, once it leaves the teacher's mind it becomes a socio-cognitive entity which, not only may affect student learning in ways unforeseen by the teacher (for example by restricting natural collaboration; see Dillenbourg, 2002), but it might also be affected by students during the process of appropriating the script within their own context (Tchounikine, 2007). From this perspective it is interesting to explore how students' self-organization process interacts with the script framework during collaboration. Tchounikine (2007) defines students' "self-organization" as "the metalevel activity that a group of learners engaged in a CSCL script may engage in so as to maintain, within the reference frame that is externally defined by the script, a more-or-less stable pattern of collective arrangement". Although in scripted collaboration the script prescribes to a great extent the conditions for collaboration, students' self-organization is expected to emerge and play an important role whenever the script allows (and perhaps encourages) them to take their own decisions for organizing the collaboration. However, as this work shows, students' self-organization (especially when students work in distance mode without the teacher being present) may also have unpredictable and undesired impact on the implementation of a collaboration script.

In the following, after a concise theoretical background, the paper presents the design and the results of the study, regarding (a) the learning outcomes of students in two conditions (individual learning vs. scripted CSCL) and (b) four different patterns of actual script implementation. The discussion is then focused on analyzing how students' self-organization (strongly connected to students' motivation and metacognitive skills) interacted with the script and even resulted to violating some specific script guidelines. As a conclusion, it is suggested that scripted collaboration may also "suffer" from students' self-organization activity and proactive teacher/designer interventions are needed to manage the script implementation in a way that students' self-organization becomes a helpful asset of the collaboration instead of a possibly threatening factor.

Theoretical Background

Scripted Collaboration and Students' Self-Organization

Collaborative learning may often result to detrimental learning due to student failure to collaborate effectively. Productive learning interactions do not happen spontaneously within the team and research has consistently revealed that freely collaborating students may lack the competence to engage in fruitful learning interactions without external support and guidance (Liu & Tsai, 2008). To heal this shortcoming researchers have suggested various approaches to guide the collaboration activity, such as intelligent CSCL (e.g., Soller, Lesgold, Linton & Goodman, 1999) and scripted collaboration (e.g., Weinberger, 2003).

The scripted collaboration approach aims to guide the collaboration activity by using specific didactic scenarios. It is suggested that by implementing an appropriate collaboration script one increases the probability of productive student-student and student-teacher learning interactions. Indeed, scripted collaborative learning has been reportedly resulted in improved learning outcomes (Kollar, Fischer & Slotta, 2005; Rummel & Spada, 2007; Weinberger, Fischer & Mandl, 2002).

Computer-supported collaborative learning scripts (or simply CSCL scripts) are computer-based representations of collaboration scripts, where the computer is employed as a means to deploy the script representation and also to support learners with communication functionalities (Tchounikne, 2008). Lately, the considerable interest that the scripting approach has gained in the CSCL community has motivated efforts for the formalization of collaboration scripts (Kobbe, Weinberger, Dillenbourg, Harrer, Hämäläinen & Fischer, 2007) and the development of computer-based environments for the authoring and operationalization of CSCL scripts (e.g., Hernández-Leo et al., 2006; Turani & Calvo, 2007).

However, even though the script provides a scaffolding framework for the collaboration, the actual implementation of a script raises two – at least – major issues that need careful consideration, before or during script run-time. First, it is the issue of avoiding "overscripting" conditions. Overscripting as Dillenbourg (2002) points out is the danger of restricting the creativeness of free (non-scripted) collaborative setting in favour of a teacher-led guidance of collaborative activity that is promoted by the scripting approach.

Second, it is the issue of script appropriation through students' self-organization activity. In free collaboration the students are expected to develop their own self-organizing patterns in order to successfully reify the activity. Instead, scripted collaboration already provides an organizing framework for the collaborating students. However, script implementation is subject to students' appropriation process, meaning that students are expected to "filter" and adjust the script to their own context during run-time. Dillenbourg (2004) underlines this distinction suggesting that one should distinguish between ideal (the activity as prescribed by the teacher), mental (the mental script representation that the group builds from teacher's prescription) and actual (the actual task and interactions that students engage) script in order to conceptualize the different teacher's and students' script perspective.

Question Prompting and Peer Interaction as Student Scaffolding Techniques

The long-term perspective of our research is how to better support students when learning in ill-structured domains, by implementing effective scaffolding techniques in technology environments. The two pillars of our scaffolding approach is (a) question prompting and (b) peer interaction.

Question prompts are sets of questions, used to guide and facilitate the learning process offering both cognitive and metacognitive support to students. They usually appear in the form of procedural, elaboration or reflection prompts and they have consistently proven to be of value in diverse situations. Research on elaborative interrogation revealed that this type of question prompts can result in greater factual and inference learning (e.g., Woloshyn, Willoughby, Wood & Pressley, 1990). Question prompts have been used in technology-enhanced learning environments to help direct students towards learning-appropriate goals such as focusing student attention, modelling the kinds of questions students should be learning to ask, and helping make their thinking visible and thus an object for reflection (e.g., Azevedo, Cromley & Seibert, 2004).

The socially oriented "peer interaction" approach to learning (or collaborative learning) is rooted in the ideas of Vygotsky (1978) who argued that interaction with others is a fundamental mechanism of learning. Several research studies (e.g., Cohen, 1994; Webb & Palincsar, 1996) provided evidence that essential learning emerges as a byproduct of the cognitive activity that can be triggered when interacting with others. It is expected that the activity initiated through peer interaction help move a person to higher levels of thinking through articulation of their own understanding, testing of arguments, modification of ideas and activation of judgment and reasoning skills (Berge & Collins, 1995).

For the purposes of our research we have developed a technology-enhanced learning environment for case-based learning (eCASE) and applied a context-based questioning strategy to support students analyze the context of complex case material. So far we have focused on conditions of individual learning and we have demonstrated that students who are being scaffolded by question prompts perform significantly better when compared to the non-scaffolded students (Demetriadis, Papadopoulos, Stamelos & Tsoukalas, 2008).

In this paper, we present the outcomes of a next study implementing a scaffolding approach that comprises both question prompts and guided peer interaction. Our objective was to record the benefits emerging for the students of the computer-supported collaborative learning condition. We expected that these students would perform significantly better than those in the individual study non-scaffolded condition. However, as we explain in the following, neither the CSCL condition achieved better learning outcomes nor the students' interaction patterns were always as dictated by the collaboration script.

Overview of the Study

Goal of the Study and Research Questions

The first goal of the study was to compare the learning outcomes between two conditions of computer-supported study in ill-structured domain: non-scaffolded individual learning vs. prompted scripted collaboration. A second objective was to investigate the scripted collaborative learning experience of the CSCL group and analyze how student teams organize their activity guided by the script.

Method

Participants

The study employed 40 Computer Science students (20 males and 20 females in their 3rd out of 4 years of studies) who volunteered to participate. The students were domain novices (this was a prerequisite for participation) and they had never before been typically engaged in case-based learning as undergraduates. Students who successfully completed all the phases of the study were given a bonus grade for the laboratory course.

The 40 students were asked to choose whether they would like to work collaboratively or not. Initially, only 8 dyads were voluntarily formed (3 male-male and 5 female-female). We additionally assigned 4 male students (selected randomly) to work in 2 dyads. Overall, the two study conditions were as follows:

- CSCL group: 20 students (10 males and 10 females)
- Individual Learning (IL) group: 20 students (10 males and 10 females)

However, a dyad dropped out during the study and so the final CSCL group distribution was 5 male-male and 4 female-female dyads.

Material

The domain of instruction was Software Project Management (SPM), a domain of considerable complexity and need for knowledge transfer in job-related situations. SPM was chosen because it is hard to teach and learning relies largely on past experiences and project successes and failures. Difficulties in this domain stem from the fact that software processes are not well-defined, their product is intangible and often hard to measure, and large software projects are different in various ways from other projects (Sommerville, 2004). In addition, many aspects of SPM are not adequately formalized and involve subjective quantification, e.g. risk prioritization. As a consequence, software managers recall and use their knowledge about projects they have managed (or are aware of) in the past, and base their decisions on management patterns and anti-patterns. It is worth mentioning that this field has been ranked first among 40 computer science topics whose instruction needs to be intensified in academia because of demands in professional context (Kitchenham, Budgen, Brereton & Woodall, 2005).

For the purpose of our research, we developed eCASE, a web environment for case-based learning. Studying in eCASE involves solving ill-structured problems, presented to students as "scenarios". A scenario is a problem-case anchoring student learning in realistic and complex problem situations in the field. After presenting the problem, a scenario poses to students some critical open-ended questions (scenario-questions), engaging them in decision-taking processes, as if they were field professionals.

Before answering the scenario-questions the learners are guided to study supporting material in the form of "advice-cases". An advice-case is a comprehensive case presenting some useful experience in the field that is relevant to the scenario problem. Hence, each scenario in eCASE is accompanied by a number of relevant advice-cases. In order to develop advice-cases we selected and adapted authentic SPM cases reported in the literature (e.g., Ewusi-Mensah, 2003; Verville & Halingten, 2001). The scenarios presented to students were about various installations of Enterprise Resource Planning (ERP) systems in new or restructured facilities, while the advice-cases referred to similar projects highlighting important domain factors such as the role of end-users, the involvement of senior management, the definition of project goals, and the changing of system requirements. Overall, the students had to suggest a possible solution to the problems depicted in the scenario (by answering the scenario-questions), based on domain past experiences presented in the advice-cases that accompanied the scenario.

Design

A pre-test post-test experimental research design was implemented to compare the performance of the two groups (CSCL vs. IL group) with two measures of the post-test as the dependent variables. Additionally, we collected qualitative data to analyze students' behaviour during the activity. The two groups proceeded through the study in five distinct phases: pre-test, familiarization, study, post-test, interview.

Pre- and Post-Tests

The pre-test was a prior domain knowledge instrument that included a set of 6 open-ended question items relevant to domain conceptual knowledge (e.g., "What role can/should the end-users play in the development of a software project?").

The post-test comprised two sections focusing on: (a) acquired domain-specific conceptual knowledge, and (b) students' potential for knowledge transfer in a new problem situation. The first section included three domain conceptual knowledge questions (e.g., "For which reasons you would encourage/discourage the involvement of end-users in the project development process?"). The answers to these questions were not to be found as such in the study material, but rather to be constructed through a generalization process, by combining parts of information presented in various occasions in the case material. The second section presented a dialogue-formatted scenario. In this scenario, various stakeholders (company CEO, CFO, clients, technicians etc.) were discussing managerial issues of an ongoing software project in an everyday professional context. Students had to identify elements in the scenario that might be indicators of inefficient management and suggest resourceful alternatives.

Procedure

In the pre-test phase, students completed the prior domain knowledge instrument. During the familiarization phase, students logged in to the eCASE environment (from wherever and whenever they wanted) and worked on a relatively simple scenario prepared for them, accompanied by two short advice-cases. Students had to read the material in the advice-cases and based on that to provide answers to the scenario open-ended questions. They were allowed one week to complete the activity. The familiarization phase was the same for all students and the objective was to help them familiarize with the content material, the study methodology and the user interface in the eCASE. Although the one week period was rather long for the provided study material, we allowed it to provide ample time for familiarization with the functionalities of the environment.

After the familiarization phase, the students continued with the study phase, which was different for the two groups. This phase lasted one week and the students had to work online on 3 complex scenarios (the same for all groups) that addressed more issues and were accompanied by 5 longer advice-cases. After the study-phase students took a written post-test in class. After the post-test, the students from each group were interviewed to record their comments on the activity.

Treatment

For the IL group the study phase was similar to the familiarization phase. The students had to study individually the advice-cases that accompanied a scenario and then propose a possible solution to the problem depicted in the scenario. The eCASE system allowed students to upload their answers to the scenario-questions, after they had navigated through all the advice-cases of the scenario. Students in the IL group were not scaffolded in any way during their study.

By contrast, students in the CSCL group were scaffolded by a collaboration script that orchestrated the collaboration activity (Figure 1). In the core of the script lies a peer review process.

1. In step 1, each student in the team studies the resource (an advice-case) and provides an answer to the prompting questions individually (see next paragraph). After both students have answered the questions, their answers become available to each other.
2. In step 2, the students (individually) have to review each others answers and identify issues of agreement/disagreement.
3. In step 3, the students have to collaborate, discuss their reviews and agree on a common final answer including also argumentation about their choice to present or dismiss issues that appeared in their individual answers. At this point eCASE provides a discussion form to support student collaboration. However, students are allowed to use the medium of their choice during discussion (e.g., face-to-face meeting, phone call, email etc.).
4. The script ends when one of the students in a dyad submits their final common answer in eCASE.

Students in CSCL group had to follow the script guidelines when answering the question prompts while studying the advice-cases. Also they applied the same script to answer the scenario questions. The eCASE system allowed students to submit their answers in the scenario-questions only after completing the study of the respective advice-cases. The collaborating students had to self-organize their activity in order to communicate and maintain an efficient pace in submitting their answers.

In order to prompt CSCL student to reflect on the case material we constructed a domain-independent prompting model to trigger those cognitive processes that are relevant to generating and understanding the context of a situation. According to Kokinov (1999), the elements of contextual information that are available to a reasoner are induced from at least three cognitive processes ("context-generating cognitive processes"): perception, memory recall and reasoning. "Perception-induced" context refers to contextual information available through perception of the environment. "Memory-induced" context refers to elements which are recalled from memory and older representations, which are reactivated. Finally, "reasoning-induced" context refers to representations that are derived through reasoning process (for example, while setting goals, defining strategy, etc.).

So, we stated three questions to prompt students to: (a) focus on important events evident in the situation (triggering the perception process), (b) relate these events and their impact to what is already known from other similar situations (triggering the memory recall process), and (c) reach useful conclusions (activating the reasoning process) based also on the results of the two previous steps. We call this the "observe-recall-conclude" prompting scheme and, more specifically the questions were stated as follows:

1. "What concrete events (decisions, etc.) imply possible problems during project development?"
2. "In what other cases do you recall having encountered similar project development problems?"
3. "What are some useful implications for the successful development of a project?"

The "recall" question provided additionally a "case archive" link for students to navigate and review relevant, already studied, advice-cases. The above questioning scheme was presented to CSCL students at the end of each advice-case they studied.

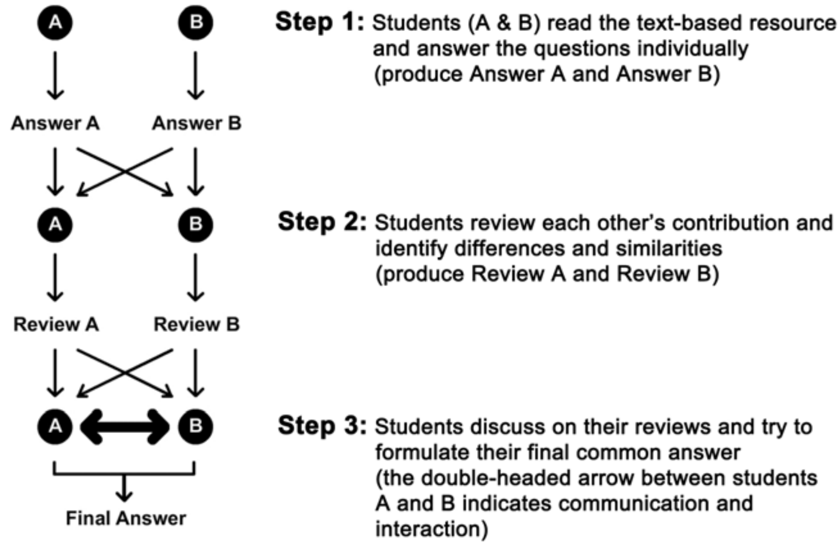

Figure 1. The ideal collaboration script for students of the CSCL group (working in dyads)

CSCL Students Interviews

We conducted semi-structured interviews to collect qualitative date on how CSCL students worked and perceived the activity during the study phase. Interviews were conducted for the IL group as well (around students' attitudes towards the learning environment and the activity as a whole), however the focus was mainly on the CSCL group and the actual scripts the dyads followed during their study. In these interviews the objective was to record students' profile as collaborators and to identify the collaboration patterns the dyads developed. Specifically, we asked students about: (a) their previous experience in collaborative course assignments, (b) their opinion about collaboration in general, (c) their criteria for choosing a partner, (d) the actual script followed in eCASE, (e) their opinion on the collaboration outcomes in eCASE, and (f) their comments about the whole activity.

Data Analysis

Students' pre-test and post-test answer sheets were assessed by two raters. To avoid any biases, the raters mixed and assessed blindly students' paper sheets for the pre- and post-test. The raters used a 0-10 scale and followed predefined instructions on how to assess each specific item. The deviation between scores from the two raters was not to exceed the 10% level (one grade on the assessment scale), else raters had to discuss the issue and reach a consensus. Eventually each student received 3 scores: (a) a score for the pre-test, (b) a score for answering domain-specific conceptual knowledge questions ("conceptual" score) of the post-test, and (c) a score for the post-test scenario analysis ("transfer" score). These scores were calculated as the mean values of the respective scores provided by the two raters. As a measure of inter-rater reliability, we calculated the intraclass correlation coefficient (ICC) for the three scores.

For all statistical analyses a level of significance at .05 was chosen. To validate the use of the parametric tests, we investigated the respective test assumptions and results showed that none of the assumptions were violated. To compare students' prior knowledge in the domain, we conducted t-test and to compare students' performance in the conceptual and the transfer measures of the post-test we conducted multivariate analysis of covariate (MANCOVA), using the pre-test score as covariate.

The interviews lasted about 10 minutes per student and were audio recorded. We used the interviews transcript for content analysis. Based on students' statements of how they engaged in the collaboration activity, we classified dyads in different interaction patterns. To further validate the reliability of our classification scheme, we also used data recorded through the system log files (such as students' actual submitted answers and login frequency).

Results

Statistical Analysis

Table 1 presents the pre- and post-test scores of the two groups. Inter-rater reliability was high for the pre-test, the conceptual, and the transfer score ($ICC = .905$, $ICC = .881$, $ICC = .856$, respectively). T-test results indicated that students were domain novices scoring very low in the pre-test and that the two conditions were comparable regarding students' prior knowledge ($t(36) = 0.168$, $p = .868$, $d = 0.060$). MANCOVA results showed that the main effect of collaboration did not reach statistical significance for the two measures of the post-test (Wilk's Lambda: $F(2,34) = 0.532$, $p = .592$, $\eta^2 = .030$).

Table 1: Students' performance in the pre- and post-test (scale 0-10).

	Individual (IL)			Collaborative (CSCL)			Total		
	M	SD	n	M	SD	N	M	SD	n
Pre-test	1.43	(0.87)	20	1.39	(0.57)	18	1.41	(0.73)	38
Conceptual measure	7.78	(1.01)	20	7.59	(1.33)	18	7.70	(1.15)	38
Transfer measure	7.75	(1.44)	20	8.11	(1.18)	18	7.92	(1.32)	38

Interviews Analysis

Students of both groups said that eCASE was "friendly" and "easy to use", even though they had not used a similar system in the past. Additionally, students underlined the role of the presented domain (SPM) on their attitude towards the whole activity, stating that it was interesting and intriguing to study about cases closely related to their future workplace. For example, student CSCL7 said:

> By proposing answers to the scenarios I felt like I was part of a company! I found it very interesting to learn about software project management problems and how demanding and complex is developing such projects in real life.

Focusing on the CSCL group, all students stated having worked in teams previously. However their experience with collaborative learning (and especially with scripted collaboration) was very limited, first because their engagement in team work occurred very few times before (one or two experiences) and, second, these experiences were rather of cooperative work (and not collaborative), as students worked on programming assignments in which parts of code development was distributed to team members. Regarding their attitude towards collaboration, all students stated that they prefer working in groups. This was expected, because students were free to choose whether they would be on the IL or the CSCL group. At this point, we should note that the students in the two dyads we formulated to balance the groups' population did not differentiate from the other CSCL students as they had the same attitude towards collaboration and achieved similar scores in the post-test. It is also worth mentioning that they were no differences between males and females in the two groups regarding both profile and performance. The potential to support learning through multiple perspectives and additional feedback on an issue was the strength that most students (n=14) identified in collaboration. Increased motivation through interaction with peers (n=3) and division of effort (n=3) were also mentioned as collaboration strengths. The majority of students (n=13) said that the option to select their collaboration partner is very important, and the lack of such freedom can affect negatively their attitudes towards collaboration (n=3). The most common criterion for choosing a partner is intimacy and personal relations (n=13), although some students noted that friendly relations is just as important as a person's level of knowledge, responsibility and ability to communicate (n=6).

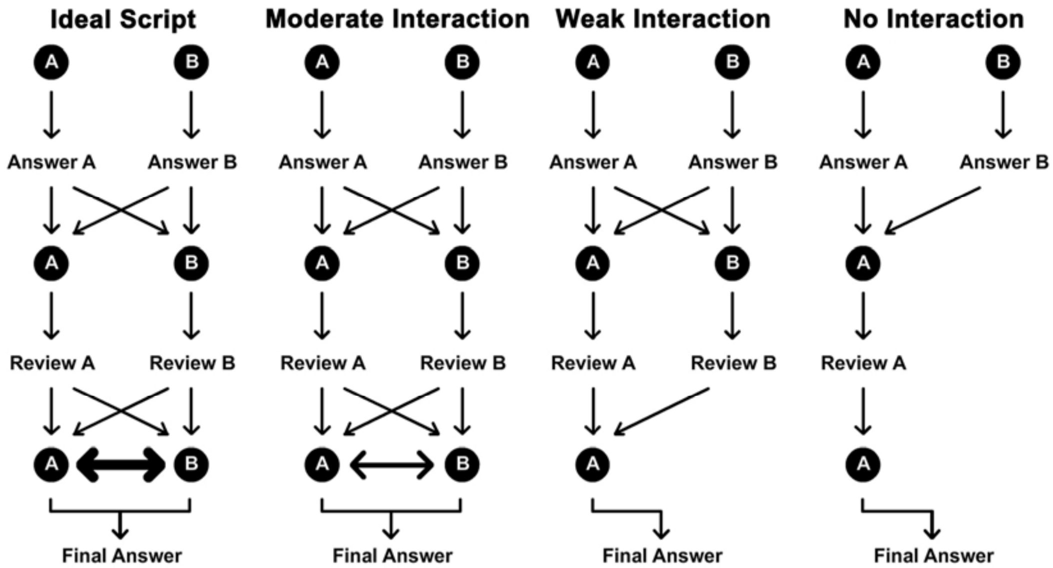

Figure 2. Actual collaboration scripts in the activity of the CSCL group

Analyzing the collaboration of CSCL dyads revealed four different actual collaboration scripts (Figure 2). Three dyads worked exactly as the ideal script prescribed. Students participated equally throughout the steps of the script and they had a meaningful discussion about the formation of the final answer. It is worth mentioning that these three dyads did not use the same medium for their discussion. Hence, while two dyads used face-to-face meetings, the third dyad used phone calls and on-line chatting extensively. This means that the selection of a specific medium was not always indicative of students' activity. Student CL17 of the third dyad stated:

> We were discussing the main issues that our final answer should analyze and the actual phrasing. For each of the final common answers we submitted, we went through 10 intermediate drafts.

The actual script of two other dyads resembled the ideal script, but with a significant decrease of the interaction between students ("Moderate Interaction" pattern). In the first dyad there was usually a brief discussion about the issues of the final answer, but only one of the students was each time responsible for the final answer. Before the final submission, the final answer was sent to the other student for approval, but this was typical as it was always approved without any comments. In the other dyad, students had agreed to always include any additional issue raised by either one. Hence, in the discussion they focused on the parts of their individual answers that they would be replicated in the final answer.

Another two dyads demonstrated a pattern with almost none interaction ("Weak Interaction" pattern). In these dyads, communication was usually one-sided. After both students submitted their individual answers, one of them was solely responsible for the formation and submission of the final answer, considering also comments sent by the other student concerning the two individual answers. The second student was seeing the final answer only after submission. Student CL6 said:

> Usually the one submitting last her individual answer was also responsible for the final answer. She had to consider her partner's comments and write and submit the final answer. We trusted one another on the writing of the final answer and we tried to divide the workload by taking turns on this task.

Lastly, two other dyads worked in a totally individual mode, as one of the students was usually completely non-participating after submitting the individual answer, while the other student had to write and submit the final answer without any feedback from his or her partner ("No Interaction" pattern). Additionally, the inspection of students' answers in eCASE revealed that in some cases students were submitting superficial individual answers, only to make the system promote them to the next step of the script. This pattern of collaboration clearly violates the ideal script as the instructions were to meaningfully answer the questions and contribute to the effort of the team through interaction and collaboration.

The degree of self-organization that student teams demonstrated was also affected by their mental script, that is, the way they understood and interpreted the ideal script (Dillenbourg, 2004). Misconceptions led students to unpredicted behaviors distant to the script's goal. For example, student CL2 said:

> I was irritated by my partner because she was submitting long and very analytical answers and this made our answers in the individual phase to differ a lot. I told her to give short answers so that it would be easier for us to submit a common final answer.

In this student's mind, agreement between partners was conceived as a script requirement and as a general goal to submit a common answer, and not necessarily a more complete answer. The examination of the answers of this dyad showed that the first student was initially submitting comprehensive and good answers, while the other student was answering poorly in short. During the week, the answers of the first student got significantly shorter and adequate analysis was often missing. Similarly, students from another dyad said that they intentionally submitted short final answers to avoid replicating phrases used in their individual answers. This is something that was not demanded by the script; nevertheless it affected students' activity.

Lastly, regarding the final answers, only three dyads stated that the final answers were improved in relation to the respective individual answers. Students felt that the final answers were more eloquent and more complete, comprising issues raised by either students. On the contrary, students in six dyads said that they did not found significant differences between their individual and final answers as both analyzed the same issues without a significant addition, except of a possible improvement on phrasing. The main reason for this was, as students said, the high level of agreement in the individual answers that resulted to very similar final answers.

Discussion and Conclusions

In this work we have explored two conditions (IL and CSCL) of computer-supported learning, analyzing (a) the level of individual learning achieved in these conditions and (b) the students' self-organization patterns in the collaborative condition. We provided quantitative evidence indicating that there was no significant difference in the learning outcomes of the two groups (as measured by two specifically constructed instruments). Students in the CSCL condition did not perform – statistically – any better than those in the IL condition. This outcome should be discussed in the light of a previous study (Demetriadis et al., 2008) where individually studying students, being scaffolded by question prompts similar to those presented to the CSCL group, significantly outperformed the control IL condition. Directly comparing the two studies would be inappropriate due to differences in the treatment of experimental groups. However, it would be apt to emphasize that while it is possible to achieve higher performance than the non-scaffolded IL condition, the CSCL scripted approach failed to help students improve likewise their learning. To analyze possible reasons we focus in the following on CSCL students' self-organization patterns.

CSCL students' self-organization affected the script implementation and resulted to a number of actual scripts, ranging from complete conformance (to the ideal script) to violation of script prescription as regards the learner-learner interaction. Based on our qualitative data we argue that three important factors had a major impact on the way that students appropriated the collaboration script.

First, the students' motivation to engage in shared understanding communication processes during script run-time. Students who enacted actual scripts with low interaction, were less motivated to engage in meaningful interactions and more oriented to finish the activity with minimal effort and in the shortest time possible.

Second, the students' metacognitive skills and awareness. Students were not familiar with this kind of scripted collaboration and were less skilful in monitoring how their level of understanding would increase through peer interaction. These students considered the learner-learner interaction as a secondary feature of the activity and missed the opportunity to reap learning benefits emerging from this experience.

Third, the design of the script itself. One should not disregard the possibility that the script might not be optimally designed to engage the specific group of students in the process of developing a shared understanding. Students reported that they sometimes perceived discussing with their partners as not necessary since their individual answers to the questions were already converging. This impression eventually rendered the joint effort to reach a shared understanding rather redundant.

Overall, we argue that students' low motivation, lack of familiarity with the method (therefore, reduced metacognitive awareness about the cognitive benefits emerging from the method) and possible suboptimal script design led certain teams of students to the enactment of actual scripts with low interaction. This, in turn, might have resulted in poor information processing and lower post-test individual performance. We can not, of course, argue that CSCL students would have achieved significantly improved performance in case they would have strictly conformed to script guidance. It seems reasonable to assume that in a situation where all three above factors were improved the students' level of learning might also have been improved, although this remains to be examined.

Nevertheless, what should be emphasized in this experience are some conclusions of importance to the teacher and CSCL designer. It is clear to us that scripted collaboration can not be considered as a panacea that has the potential to unconditionally heal the shortcomings of free collaboration. The teacher interested in applying the method should be aware of the fact that the interaction of factors such as students' lack of metacognitive skills, low motivation and suboptimal script design may lead to actual script implementation different to the ideal, that inevitably will undermine the hypothesized pedagogical value of the script. As a remedy for such a situation we suggest that the teacher should beforehand explore students' prior experience regarding scripted collaborative activities. For inexperienced students the teacher should propose/design a script where the learning mechanism and the emerging peer interaction would be clearly perceived by students as an important and necessary part of the overall activity. Moreover, for low motivated students it seems doubtful whether scripted collaboration can increase their engagement in the collaborative task by means only of cognitive guidance and support. It is suggested that a script can integrate motivational and metacognitive scaffolding as well to stimulate students engage in the process of developing a shared understanding; these components could be adaptively activated depending on the identification (by the CSCL system or the teacher herself) of students' detrimental self-organization patterns of behaviour.

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Human Guidance of Synchronous E-Discussions: The Effects of Different Moderation Scripts on Peer Argumentation

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Abstract: Researchers and educators have considered synchronicity as a less desirable mode of communication than a-synchronicity in learning tasks involving discussions. This is because synchronicity does not easily allow students to take into consideration collaborative scripts in the heat of discussions. Also, moderation by teachers of synchronous discussions has been considered as extremely challenging so far. We describe here a study in which we trained students-teachers to moderate synchronous discussions and asked them to moderate discussions in two different ways of guidance, social and argumentation guidance. We show that moderation of synchronous discussions is feasible as effects of moderation on argumentative, social and interactive aspects of the discussion reflect the kind of guidance suggested. Also we show differences between girls and boys in the way they participate in synchronous discussions and respond to the moderator's suggestions.

Collaborative scripts, collaborative learning and the agenda of the CSCL community

Rogoff's publications since her memorable *Apprenticeship in thinking: Cognitive Development in Social Context* (1990) to *The Cultural Nature of Human Development* (2003), uncover an interesting shift. If Rogoff championed first unguided peer interaction as a fundamental context for development and learning besides guided participation, it later disappears, leaving guided participation as the basic mechanism through which learning takes place. The term "transformation of participation" Rogoff uses to describe learning processes, probably hints to the fact that collaborative learning tasks are settings in which children or learners collaborate but in which they have difficulties to function without any kind of guidance. The guidance may be provided by the institutions, or tools that afford collaborative settings. In formal education, guidance is more direct. For example, in argumentative settings, learners have difficulties in co-constructing adequate arguments and interacting productively (Kuhn, Shaw, & Felton, 1997; Mandl, Gruber, & Renkl, 1996). Even adult discussants rarely warrant or qualify their claims and thus rarely construct complete arguments. Furthermore, discussants are often unable to balance and integrate arguments and counterarguments critically. Simply asking learners to collaborate is not sufficient for fostering argumentative knowledge construction. This situation is very challenging for the young CSCL community that has put collaboration at the foreground of learning activities. Of course, the CSCL community does not ignore the crucial role of guidance. However, this role has been often delegated to computerized tools specially designed to enable collaborative learning through representational affordances (Suthers, 2003), or automated messages sent to students during their learning activities. For example, asynchronous computer-supported collaborative learning environments have been regarded as suitable contexts for facilitating argumentative knowledge construction (Andriessen, Baker, & Suthers, 2003; Marttunen & Laurinen, 2001). Learners communicate in an unspecified sequence via text-based interfaces and are thus able to type and read messages at their own individual pace. Such an environment gives learners more time than face-to-face learners to both compose their own messages and understand the messages of their learning partners. Besides the time advantage, learners who communicate asynchronously via computer can repeatedly access previous arguments and can easily revise the wording of their own arguments (see Pea, 1994). But such environments do not provide sufficient support for collaborative learning. Computer-supported scripts have been considered as possibly supporting argumentative knowledge construction to improve individual knowledge acquisition. Collaboration scripts provide instructions for small groups of learners on what activities need to be executed, when they need to be executed, and by whom they need to be executed in order to foster individual knowledge acquisition. Computer-supported scripts aim to directly influence the interaction patterns of collaborative learners rather than train learners prior to actual collaboration. Consequently, computer-supported collaborative learning is often facilitated by the design of the interface (Baker & Lund, 1997; Scardamalia & Bereiter, 1996).

Research on the impact of scripts on the effectiveness of collaborative learning is not voluminous. In a series of seminal papers, Weinberger, Fischer and their colleagues (Weinberger, Ertl, Fischer, & Mandl, 2005; Weinberger, Stegmann, & Fischer, 2005) have studied how collaborative computer-supported script components may facilitate argumentative knowledge construction. They first defined problem-based scenarios for facilitating argumentative knowledge construction to differentiate between epistemic, argument, and social modes dimensions of co-construction (Weinberger & Fischer, 2006). University students were organized in three groups of triads, each group being prompted with *epistemic*, *argumentative* and *social* script components respectively during the solution of a problem. All computer-supported script components substantially reduced off-topic discourse, hence helped focusing on the task and facilitated the specific processes of argumentative knowledge construction. All script components seemed to have the general effect of focusing learners on the script components guide and inform learners of what to do next to solve the task in one way or another. The epistemic script components helped learners constructing arguments that contribute to solving problem cases, but the individual benefits from this support were found dubious. Weinberger et al justified this finding by suggesting that epistemic script components may enable learners to solve the tasks with a limited elaboration from their own side. Also, they judiciously claimed that advanced learners may already possess functional strategies for solving a task and additional epistemic scripting might simply distract learners from the actual task. The argumentative script component was able to support argumentative knowledge construction in both the formal argumentation process dimension during discourse and individual knowledge acquisition. Argumentative script components functioned as thinking tools to amplify elaboration, but failed to prompt learners to use the relevant knowledge concepts that are to be learned. Social script components were the more productive. They supported learners in inquiring about the contributions of the learning partners more critically and thereby helped them acquire more knowledge individually than learners without additional support in the dimension of social modes of co-construction. They were found as superior to the other scripts concerning knowledge acquisition.

The contribution of the studies done by Weinberger and colleagues are landmarks in the recognition of the necessity of guidance in collaborative setting. However, we should reflect on the kind of guidance these studies focused on and whether it fits the scope of the CSCL community. In the scripts described above, instructions were not contingent to previous actions in the discussion but were built-in and impersonal. It is well known that epistemic script components need to be carefully matched with the individual prior knowledge of the participants. Otherwise, an over-scripting effect (Dillenbourg, 2002) may distract learners from the solution of the task. Also, epistemic scripts facilitate tasks and it may be preferable to turn collaborative learning tasks harder instead of simplifying and facilitating the active elaboration of the learning material (Palincsar & Herrenkohl, 1999; Reiser, 2002). Content-independent argumentative script components may aid elaboration, but hold the danger that learners may not be able to select the appropriate concepts that are supposed to be elaborated. These pitfalls may explain the relatively low effectiveness of the epistemic and argumentative scripts. The social script component of this study was productive: it managed to not only facilitate transactive discourse, but also supported the epistemic activities of learners. However, was this script really social in a sense which is fully acceptable in the CSCL community? According to the social script, students were invariably asked to analyze a text, elaborate their arguments, and to criticize the arguments of their peers. Such a view of social script sees the other as the receptacle of an argument to be analyzed and criticized, nothing dialogic, and relational. We intuitively know that although we should be attentive to the contributions of our peers, it is often superfluous, even harming, to criticize when there is no need to do so.

Our aim in the present study is to explore guidance in argumentative knowledge construction in a way which seems to us closer to the scope of the CSCL community. According to a socio-cultural approach largely adopted in the CSCL community, guided participation is effective when guidance is sensitive to the learner's needs and attuned to his/her attention and previous actions (Rogoff, 2003). Our approach has been to design a tool for collaborative argumentative construction of knowledge. This tool, which is succinctly described later on, enables synchronous argumentation. We then trained teachers to help students in small group collective argumentation and asked them to guide knowledge construction in small group argumentation in two different ways. Like Weinberger and colleagues, students worked on a task in small groups (3-4 students) and were gathered in groups where guidance was designed in a different way. However, the design of guidance consisted in asking teachers to follow different kinds of instruction. The instructions the teachers received had a different status from scripts since the decisions about when to intervene, to whom to direct interventions, and how to intervene was left to teachers in the course of synchronous e-discussions.

Collaborative argumentation with synchronous graphical tools: the case of the Kishurim program

The Kishurim program is an educational initiative developed in Israel to foster argumentation and dialogic thinking in schools since 1998 (Schwarz & de Groot, 2007). The program includes pre- and in-service teacher training programs, in order to support teachers in integrating argumentative activities in their classes. The Kishurim program is based on several pedagogical principles, among them: favoring collaborative tasks, non-intrusive procedural mediation, commitment to critical dialogue and civilized, reasoned communication.

We coordinated the development of the DUNES environment in an EC funded project (IST-2001-34153), which provides a platform for e-discussions in synchronous or a-synchronous mode. The objective in DUNES was to design, implement and test an environment for collective argumentation. In order to motivate students to engage in discussions, we proposed the development of ‘cases’ (based on ‘ill-structured’ or ‘wicked 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. The main technological outcome of this project was the development of Digalo (http://zeno8.ais.fraunhofer.de/digalo/index.html). This graphical discussion tool enables the management of argumentative discussions and the representation of argumentative processes and components among participants. Group discussions in Digalo consists of co-creating maps built of textual contributions inside geometrical shapes and different arrows (supporting, opposing, and linking) representing different connections between the shapes. The output from this activity is then a collaboratively constructed argumentative diagram (see Figure 1). Each discussant works on a personal computer and sees the display on the on-going argumentative map while constructing his/her own contribution. The different geometrical shapes constitute the ontology that specifies and constrains the kinds of argumentative moves discussants choose during their discussions. The tags for the different shapes may be specified by the teacher. In the present study, the array of shapes students could chose from were "idea", "claim", "explanation", "argument", "comment", and "question". Together with the three different types of arrows, this ontology covered various kinds of argumentative moves. Figure 1 shows a part of an e-discussion between four students.

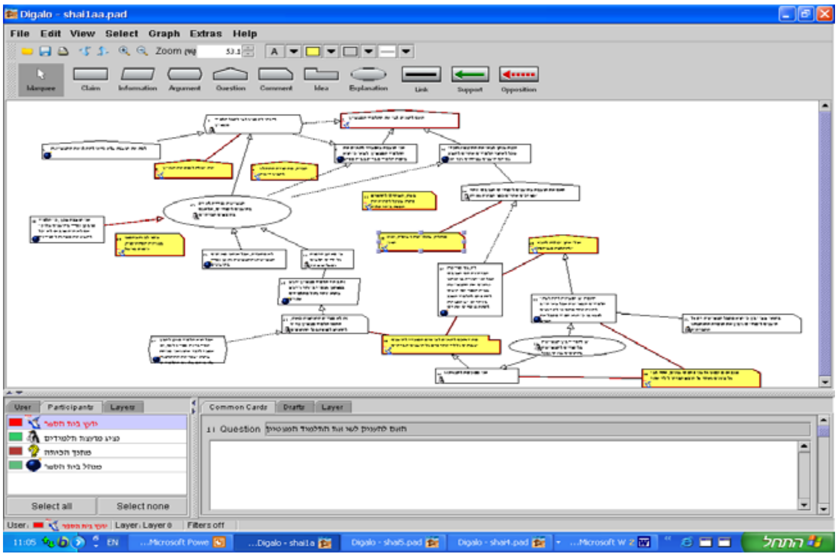

Figure 1. An example of a Digalo discussion map

In this map, the upper bar displays the pallet of tagged shapes to be chosen from. The lower left window displays the icons of the four discussants that are attached to each shape in the map. Discussants may write the title of their contribution in the title rubric (visible at all times). The content of their contribution is visible when hovering over a shape or by opening a shape by double-clicking on it. The yellow shapes in the map are the interventions of the teacher.

The potential advantages of diagram-based representational tools for peer argumentation have been reported elsewhere (e.g., Van Amelsvoort, Andriessen, & Kanselaar, 2007; Schwarz et al, 2003). They include among others, the increased ability to clarify relations, to illustrate the structure of argumentation, to promote reflection and to deepen the discussion space (see Van Amelsvoort et al, 2007, for an overview). The advantages of and difference uses of diagram-based tools in learning is not the focus of the present study. However, it is important to specify the way diagram-based tools were used in this study so as to enable proper comparisons with other findings. One way to integrate diagram-based activities in peer argumentation is to have students construct argumentative diagrams (maps) before or during face-to-face or chat-based communication (e.g., Van Amelsvoort, 2007). In these cases, the map presents the underlying structure of an individual or collaborative argument. However, in our study students *only* communicate through the argumentative map, and therefore, the argumentative map is both the representation as well as the communication mode.

The modes of communication in Digalo are either synchronous or a-synchronous. In spite of the advantages of a-synchronicity for knowledge construction in collaborative argumentation, synchronicity is another fruitful mode of communication, which seems to be even more promising than a-synchronicity. Of course, synchronous CMC suggests, to the contrary, impeding learning: It involves disrupted turn adjacency. Overlap in synchronous CMC can also prove to be problematic: In dyadic communication, users—unable to tell whether their interlocutor is in the process of responding or not—may become impatient and send a second message before a response to the first has been received, resulting in incomplete or interleaved exchange sequences (Condon & Cech, 1996; Marvin, 1995). In group communication, unrelated messages from other participants often intervene between an initiating message and its response (Murray, 1989). According to

Herring (2001), these problems are responsible for incoherence, and for topic decay – the fact that discussants rapidly discuss less and less the topic at stake during e-discussions.

Despite these shortcomings of synchronous CMC systems as conversational environments, they are often viewed as more socially desirable than analogous face-to-face interaction or a-synchronous communication—in Walther's (1996) term, as 'hyperpersonal' rather than as 'interpersonal' interaction: weakening of coherence between messages induces humorous style. The fact that in contrast with spoken discussions, no norms are prescribed on discussants enables them to participate in parallel discussions and to play. Several researchers studied the contents of CMC messages to show the presence of affective as well as interactive-cognitive expressions (Rourke, Anderson, Archer, & Garrison 2001). Rourke and colleagues (Rourke et al. 1999) showed that a-synchronous e-discussions are deeper and more filtered (with less emotional and more cohesive responses) since delay causes more reflection by less social involvement. On the other hand, students enjoy synchronous discussions more. Thus the "attractions" of CMC can be seen as the flip side of the "incoherence" coin—loose inter-turn connectedness and overlapping exchanges have both advantages and disadvantages, depending on the purposes for which users engage in computer-mediated interaction. Users are thought to be able to participate in simultaneous multiple interactions without getting hopelessly lost or confused because there is a typed record to which they can refer to keep track of what is going on.

In spite of the social/collaborative promises of synchronous discussions, research on their impact on learning processes is embryonic. Schwarz and Glassner (2007) studied graphical synchronous Digalo-discussions to suggest their superiority over other modes of communication for knowledge construction for two reasons: First, the use of ontology causes a delay inherent to the action of choosing an appropriate category, and as such invites reflection. Secondly, the tools encourage discussants to be engaged in their discussions. However, the researchers identified frequent cases in which students went astray from the discussion proposed, a fact that suggests the importance of guidance in such synchronous graphical discussions.

Description of the research

Our overall purpose in the present research was to study the impact of different kinds of human guidance on small group synchronous discussions with the Digalo software. We also planned to compare boys and girls in discussion groups with discussants of the same gender concerning the impact of guidance on synchronous discussions. To define the different kinds of guidance, we first undertook a pilot study to observe intuitive guidance in teachers trained to use Digalo and to foster dialogic thinking in students (Gil, Schwarz & Asterhan, 2007). We showed that teachers adopt various moderation styles in small group synchronous discussions. Some of the styles, such as for example the 'observing' style, expressed the difficulties teachers encounter when moderating synchronous discussions. Other styles, such as the 'authoritative' and the 'involved' styles expressed types of moderation which are not acceptable in the CSCL community (see Gil et al, 2007). The two remaining styles identified on the other hand, namely the 'orchestrating' and the 'scaffolding' styles, represented reasonable ways to guide synchronous discussions. In the present paper, we use the terms *social guidance* and *argumentation guidance* instead of 'orchestrating style' and 'scaffolding style'. The meaning of these types of moderation is clarified later on, when they are used as instructions to teachers before they guide synchronous discussions. We should only say at this point that the meaning of the term "social" in "social guidance" is quite different from the term "social scripts" as employed by Weinberger and colleagues.

Hypotheses

We expect that the effect of human moderation that focus on the scaffolding of reasoning and argumentation will improve the discussion features on measures that assess the argumentative quality of the discussion, but will not necessarily improve the extent of participation and interactivity. In contrast, it is expected that human moderation that focuses on social aspects of the activity will increase rate of participation and extent of interactivity between discussants, but will not improve the overall argumentative quality of the discussion. Concerning comparison between boys and girls, studies in feminist psychology have proposed that girls have a different cognitive style ('connected cognition'), such that girls are more socialized in problem solving tasks and discussion practices and they tend to take into consideration more of their own personal knowledge (e.g., Miller, 2005). This means that they are expected to refer more to others and to their own experience in problem solving than boys are. Although it is difficult to separate between feminist ideology and experimental ecology in many of the publications on gender differences in cognition, we expected that in our settings all-girl groups would show higher measures of off-task behavior, participation and interaction, compared to all-boys groups. Our hypothesis was fuzzy, though, since sound empirical studies on the comparison between behavioral differences between boys and girls in peer-to-peer e-discussions in educational settings, are few.

Population

85 Grade 9 students from one school participated in the study (44 male and 41 female). Three teachers participated. The school was chosen by the Ministry of Education as one of the schools in which novel teaching

strategies in technology-based environments were promoted. Every teacher who participated could make use of one hour per week for implementing the Kishurim program on dialogic thinking. In the school, many of the courses were learned in same-gender half-classes. The teachers were trained on dialogic thinking and argumentation and to design cases they chose (mainly societal dilemmas). The teachers were also trained to moderate synchronous discussions with Digalo. The teachers were asked to implement the cases they designed in their classes. The training consisted of 8 meetings of 4 hours long each. In the classes, during the weekly hour dedicated to dialogic thinking, students learned about argumentation, about goodness of arguments and discussions were trained to extract arguments from texts and to discuss social dilemmas in small groups. Students experienced very quickly the use of the Digalo tool. After designing and implementing several cases in their classes, the teachers designed three cases for our experiment. We report here on the second case.

Types of guidance

Instructions for two types of guidance were given to moderators. For the argumentative guidance, the instructions were the following:

> "In this experiment, our goal is to mediate discussions and encourage students to raise counterarguments and multiple perspectives. Please, read the contributions of each of the students and identify one possible opportunity for intervention: (a) one of the claims is not reasoned; (b) no counterargument has been raised; (c) no additional perspectives have been raised; (e) an argument is not clear; (f) a student is idle. We suggest you to choose one of the following prompts for your intervention: (1) <u>Prompts for broadening the discussion space</u>: (i) Are there more alternatives; (ii) Can you say something more about the issue? (iii) Does somebody want to oppose to Moses? (2) <u>Prompts for clarifying messages</u>: (i) What do you mean here? (ii) Could you clarify what you wrote? You are invited to intervene at least 5 times but not to be too much active in order to avoid interrupting the flow of the discussion. If students don't react, please add the following comment outside the chain of reasoning: Boys/Girls, please consider my suggestions!"

For the social guidance, the instructions were the following:

> "In this experiment, our goal is to mediate discussions and encourage students to react to each other. Please, read the contributions of each of the students and identify one possible opportunity for intervention: (a) one of the claims is different from the others; (b) one of the claims is not reasoned; (c) a counterargument has been raised and nobody reacted to it; (d) somebody brought an example which is worth sharing; (e) nobody referred to an interesting reaction; (f) a student is idle. We suggest you to choose one of the following prompts for your intervention: (1) Refer to what Moses says; (2) Does somebody want to react to Moses? (3) Does somebody want to oppose to Moses? (4) Does somebody want to strengthen his view or to ask him question? (5) Give you opinion on what was said. You are invited to intervene at least 5 times but not to be too much active in order to avoid interrupting the flow of the discussion. If students don't react, please add the following comment outside the chain of reasoning: Boys/Girls, please consider my suggestions!"

Materials

Each of the three teachers designed one activity based on a dilemma. Each of the three activities included a preliminary stage during which students watched at movies or attended to a presentations, and read texts, and articles from newspapers. After this preliminary stage, the teacher asked a question to be discussed in groups of 3-4 discussants with the Digalo tool. The question was not directly addressed in the preliminary stage. The three activities concerned: (1) sex-segregation in science learning; (2) sex education; and (3) dieting behaviors. We do not describe in detail the materials created for each of the three activities. We list here the materials created for the first activity (separation in learning):

- Three newspapers articles in favor of or against separation between girls and boys in learning
- A TV broadcast that presented a simulation of a discussion in a legislative commission about separation between girls and boys in science education
- A classroom activity to extract arguments from the three articles

After the preliminary stage, students were asked to answer the following question: The Cohen family decided to send their son Ezekiel in a school in which there is a separation in science learning between boys and girls. Do you think that the Cohen family has taken the right decision?

Procedure

The students were organized in groups or three or four students. Since the lessons were given in six half-classes of 12-16 students, four groups of students participated in four discussions in parallel. The groups were formed by the teachers according to social affinity. In each group, one student was asked to organize the map. In each half-class, the teacher moderated one discussion according to her pedagogical style. Two members of the research team moderated one group each according one out of the two kinds of instruction for guidance. One group did not receive any human moderation. As mentioned above, half-classes included students with the same gender. Overall the experiment involved 12 groups of 3-4 boys and 12 groups of 3-4 girls.

Analysis of the data

18 discussion maps were collected. Also, the preliminary stage of each case was fully recorded and analyzed to identify all ideas that arose during it. Such an operation enabled us to identify text-based and non text-based ideas that emerged during the synchronous Digalo discussions. The answers to the research questions we asked concerned the impact of type of moderation (argumentation script, social script, or without human moderation) on the discussion as a collective product. Consequently the discussion group was the unit of analysis. To analyze the maps we adopted a methodology inspired by Rourke, Anderson, Archer and Garrison (2003) and by Lotan (2006) and by dimensions proposed by Lund (2004). We focused on the argumentative, the social and the interactive aspects of discussions at three levels of analysis. The micro-level concerns argumentative moves concretized with the Digalo tool as choosing a shape, writing its content and using an arrow to link it to another shape (of course, in this case the discussant undertakes three actions but they merge to one unique argumentative move). The meso-level concerns a chain of argumentative moves linked with arrows. This level helps scrutinizing the interactive aspects of the discussion and the development of arguments. The macro-level concern the map as a whole. It helps determining general characteristics of discussions. For now, we only report on the number of different perspectives that were considered in the discussion (further analyses on map level are currently conducted).

Concerning the argumentative dimension, at the micro-level, a message was identified as a *claim* when it expresses a viewpoint and as an *argument* when it expresses a claim and (a) reason(s) supporting it. We also considered a message as an argument when it expressed a conclusion and (a) justification(s) or an assumption and (a) conclusion(s) (Angel, 1964; Kuhn & Udell, 2003; Scriven, 1976). An argument was identified as simple if it included one reason/justification only, and complex when it included more than one reason/justification. We also checked the source of arguments raised to discern between reasons based on external textual sources and non-text arguments (Schwarz, Neuman, Gil & Ilya, 2003). Arguments based on texts can be extracted from texts, and any source of knowledge given by the teachers before the discussion. At the meso-level, we checked chains of reasoning including a continuum of reasons/justifications and other argumentative moves (Asterhan & Schwarz, 2009) in which more than one discussant contributed. This continuum may include links of any kind (supporting, opposing or neutral) and should include at least two on-task contributions by different students. To identify chains of reasoning, we first expurgated from the map all the off-task and the not-content related messages. Figure 2 shows graphically how chains of reasoning were identified. This enabled us to identify the number of shared chains of reasoning. We distinguished between chains in which a collaborative argument was developed (when a claim was developed into an argument or into a complex argument), to those in which no argument was developed.

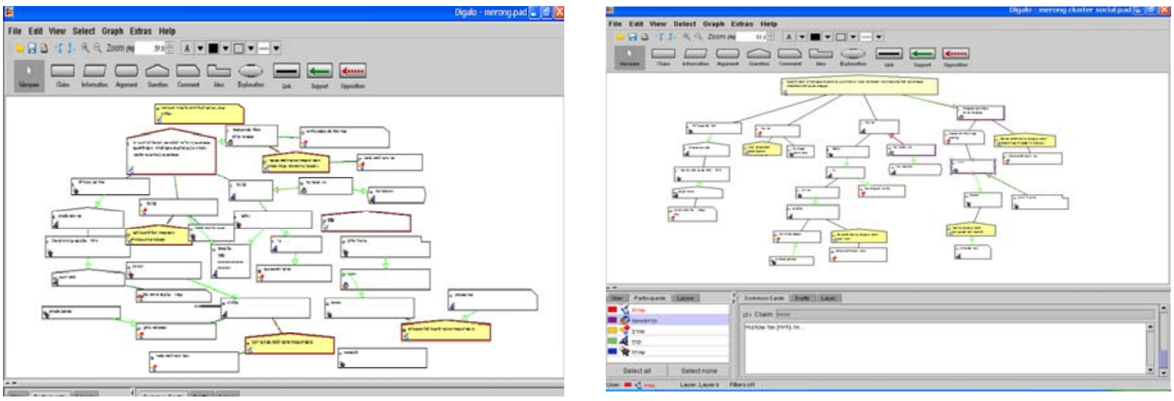

Figure 2. An original Digalo discussion map (on the left) and the same map after its re-organization according to chains (on the right)

As for the social dimension of the peer discussions, we focused on student participation and interactivity. The degree of *participation* was measured by the average number of textual contributions and links per student, and the quality of these contributions (whether they were on-task or off-task). *Interactivity*, on the other hand refers to the extent to which student discussants interacted with each other and with the moderator. Measures of interactivity concern, for example, the mean number of links to contributions of fellow students and to the moderators' contributions, the mean number of contributions that received no response and the overall extent to which contributions were inter-connected (connectivity). The social network (De Laat, Lally, Lipponen & Simons, 2007) that students constructed was measured by the density of interactions between discussants

(Scott, 1991), that is: the number of actual interactions (links) between any two discussants, divided by the maximum number of possible interactions (links) in the group. A high ratio would point at a high social density.

Results

To test our hypotheses concerning the effect of moderation that focuses either on argumentative or on social aspects, we compared the discussion features of the maps in each of these two experimental conditions with the control condition (no human moderation) (see Table 1). All comparisons were conducted with one-tailed t-tests, with corrections for violations of the homoscedasticy axiom, when necessary. It should be noted that on six of the 18 different measures (namely, number of simple claims, number of reasons based on personal judgment, extent of consensual /critical referencing, number of chains without argument construction, number of unlinked shapes and connectivity) a lower numerical value indicates a higher measures of argumentative quality or interactivity, respectively.

Table 1. Discussion characteristics of on-line Digalo discussions, by type of moderation condition (argumentative script social script or no moderation) and discussion dimension

	Moderation: Social script (N = 6)			No Moderation (N = 6)			Moderation: Argumentative script (N = 6)	
	M	*SD*		*M*	*SD*		*M*	*SD*
Argumentation								
Nr. of simple claims p.p.	1.41	.70		.99	.76		.58	.39
Nr. of simple reasoned arguments p.p.	.82	.46		.97	.50	*	1.78	.86
Nr. of complex reasoned arguments p.p.	.72	.65		.43	.46		.26	.50
Nr. of reasons based on external sources	.93	.78		.99	.76		1.33	.70
Nr. of reasons based on personal judgment	1.63	.82		1.10	.61		.99	.78
Extent of critical referencing (supportive / opposing links)	3.31	4.78		2.13	2.44		1.33	1.54
Nr. of chains with argument construction	1.50	1.05		1.17	1.17		1.67	1.21
Nr. of chains without argument construction	2.50	1.97		3.00	2.00		1.83	1.17
Nr. of different perspectives p. group	4.50	1.22		4.83	1.72		4.33	1.63
Participation								
Nr. of shapes created p.p.	6.26	1.68	*	4.07	.36		4.57	1.64
Nr. of links created p.p.	7.38	3.86	*	3.77	1.91		5.08	2.62
Nr. of on-task contributions p.p.	4.28	1.36		3.43	2.25		4.22	1.61
Nr. of off-task contributions p.p.	1.54	2.25		.72	.72		.40	.71
Interaction								
Nr of links to fellow students p.p.	4.33	1.25	*	2.40	1.39		2.58	1.73
Nr. of links with moderator p.p.	2.38	1.39		-	-		2.65	1.75
Nr. of unlinked shapes p.p.	.47	.36		.68	.51		.56	.50
Connectivity (shapes / links)	.95	.28		1.08	.18		.97	.25
Interaction density	3.44	1.46	*	2.08	1.06		2.44	1.77

* p < .05, one-tailed

The data in Table 1 show that the overall results seem to confirm our expectations: The maps in the argumentative moderation script condition showed higher values on many of the argumentative dimension measures: Students who received moderation aimed at increasing argumentation, posted more individual reasoned arguments, based their reasons on textual resources more often, used more opposing links and more often collaboratively constructed chains of reasoned argument. However, due to our small sample size and relatively large variance on the measures, these differences proved to be statistically significant for the number of simple reasoned arguments only. In contrast, the maps in the social moderation script condition showed higher measures of participation and interactivity on all eight measures of participation and interactivity: They significantly created a larger number of individual shapes and links, interacted significantly more with fellow peers and the interaction density of the overall actibity was significantly higher.

We then turned to a comparison between the discussions of all-male and all-female groups (see Table 2). Since we did not have any specific expectation concerning the direction of these differences, all analyses in this table were conducted with two-tailed t-tests.

Table 2. Discussion characteristics of on-line Digalo discussions by gender (all-girls or all-boys groups)

	All-female groups (N = 12)		All-male groups (N = 12)			
	M	*SD*	*M*	*SD*	t (22)=	
Argumentation						
Nr. of simple claims p.p.	1.27	.79	.81	.58	1.622	
Nr. of simple reasoned arguments p.p.	1.28	.55	.99	.78	1.080	
Nr. of complex reasoned arguments p.p	.85	.75	.30	.26	2.433	*
Nr. of reasons based on external sources	1.26	.81	.81	.55	1.595	
Nr. of reasons based on personal judgment	1.78	.85	.83	.57	3.205	
Extent of critical referencing (supportive / opposing links)	2.98	4.14	2.10	1.99	.667	
Nr. of chains with argument construction	1.67	.98	1.00	.95	1.685	p = .053
Nr. of chains without argument construction	2.58	2.15	2.50	1.62	.107	
Nr. of different perspectives p. group	5.25	1.76	3.91	1.31	2.101	*
Participation						
Nr. of shapes created p.p.	5.98	1.62	3.85	1.57	3.267	***
Nr. of links created p.p.	5.85	2.03	4.34	3.44	1.314	
Nr. of on-task contributions p.p.	4.83	1.51	3.27	1.57	2.470	*
Nr. of off-task contributions p.p.	.99	1.66	.61	.70	.734	***
Interaction						
Nr of links to fellow students p.p.	3.34	1.33	2.42	1.68	1.481	
Nr. of links with moderator p.p.	2.50	1.90	1.17	1.40	1.960	p = .063
Nr. of unlinked shapes p.p.	.69	.50	.52	.43	.913	
Connectivity (shapes / links)	1.06	.26	1.03	.24	.245	
Interaction density	3.15	1.21	1.88	1.38	2.405	*

* $p < .05$, *** $p < .005$, two tailed

The data in Table 2 show that on average, girls participated more than boys: they posted a significantly larger number of contributions, both on- as well as off-task communications. They also interacted more with each other and with the moderator. As for the argumentative quality of their maps, overall girls scored higher on all the argumentative measures (larger number of claims, simple and complex arguments, included more textual as well as personal reasons in their arguments, constructed more chains of both kinds, and considered a larger number of perspectives), but boys showed more opposition and criticism in their maps. A particularly interesting finding concerns the fact that girls communicated more than boys with the moderator. However, these differences proved to be only significant for the mean number of individually posted complex arguments per person.

Discussion

At a superficial level, the results of the present study may seem trivial. The argumentative moderation script led to higher measures of argumentative dimension of the discussion: more individual reasoned arguments, more opposing links and more chains of reasoning. Concerning the social moderation script, it led to more participation and interactivity. However, we should remind that synchronous discussions are new practices, and moderation of synchronous discussions has virtually not studied experimentally. Our study shows that moderation of synchronous discussions is a feasible practice for which scripts have an impact that reasonably fits the intentions of the givers of the instructions. The relatively small number of groups has probably avoided us to find stronger effects.. We intend to include more subjects to the study to check whether the strong tendencies we obtained in the present study reflect effects of moderation scripts.

Concerning gender differences, it appears that the fuzzy hypothesis concerning the fact that girls whose cognitive functioning has been described as more connected to personal experience and to others has been largely confirmed. We suggest that the nature of the Digalo tool that affords the expression of explanations and the reference to others may have amplified differences between girls and boys. And indeed, girls participated more than boys and posted more complex arguments. We are aware that the small number of groups avoids being more decisive about the lessons of this study. However, it opens a new interesting venue to gender differences in computer-mediated discussion practices in learning tasks.

We focused in this study on the tangibility of a new practice, moderation of synchronous discussions. A natural step should be to check learning gains. We are uncertain whether to do so by comparing between individual knowledge in subjects before and after discussions or to trace characteristics of discussions in successive synchronous meetings. In any case, moderation of synchronous discussions is a kind of guidance which blends strong socialization between students, minimal intrusiveness of the moderator, and at the same time, care of the group. This special blend, we think, should turn the practice to central in schools. As mentioned at the beginning of the paper, the rigidity of collaborative scripts, the fact that they are not given timely to the right students is problematic according to the CSCL agenda. We believe that moderation of synchronous discussions which personalizes interventions and provides help and suggestions according to the on-going flow of the discussion provides an excellent option for the CSCL community.

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Towards embedding assessment in CSCL scripts through selection and assembly of learning and assessment patterns

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Abstract. Assessment is one of the key elements of learning scenarios, both in individual and collaborative learning. Thus, embedding assessment in Computer Supported Collaborative Learning (CSCL) scripts can potentially enhance the enactment of collaborative learning sessions, by explicitly indicating how assessment is to be carried out. However, assessment design has also been recognized as a demanding task for non-expert instructional designers or practitioners. To tackle this problem, the use of learning and assessment patterns has already been reported as a way of supporting script design for non-experts. In this context, the combination of patterns of different nature (learning-oriented and assessment-oriented) can be regarded as an essential task of CSCL script design. This paper discusses how to support this task, focusing on the joint application of patterns, and describes an evaluation of the proposed approach.

Introduction

CSCL macro-scripts have shown to be an effective means to organize collaborative learning activities and in this way increase the chances of fruitful interactions among participants (Dillenbourg, 2002). Among the aspects that need to be defined in a CSCL script, we can highlight the assessment strategy. Assessment should be considered as a means to improve learning (Black & Wiliam, 1998; Shepard, 2000). Moreover, the specific characteristics of collaborative learning determine the appropriate assessment strategies (Boud, Cohen & Sampson, 1999), including the need of valuing adequately collaborative work or the interactions between students. In the context of the design of CSCL macro-scripts, assessment and other script components, such as activities, role distribution, or sequencing of activities (Kollar, Fischer & Hesse, 2006), are strongly interrelated. Therefore, it can be argued that assessment should be designed jointly with learning activities, and that collaboration scripts should contain information relative to its assessment plan (Villasclaras-Fernández et al., 2009).

However, embedding assessment in CSCL scripts adds a new layer of complexity to the design task, especially when the designer has limited experience of scripting or collaborative learning. Designing CSCL scripts has been the object of several research efforts. Among them, we can highlight the *create-by-reuse* framework (Hernández-Leo et al., 2007), that describes the approach of building complete CSCL scripts by reusing existing components. Different types of components can be employed, which may describe, for instance, resources, tools, or learning activities. Design patterns have shown to provide valuable support to this approach. For instance, Collaborative Learning Flow Patterns (CLFPs), a kind of pattern that capture good practices in structuring collaborative learning activities, such as *jigsaw* or *pyramid*, can be used to define the structure (sequence of activities and groups) of a whole CSCL macro-script or part of it (Hernández-Leo et al., 2006). Thus, CLFPs suggest structures of collaborative activities that can be applied in a wide range of learning scenarios.

Focusing on collaborative learning and this pattern-based design approach, Collage, an IMS Learning Design (IMS-LD, see IMS, 2003) authoring tool that supports the user in the design of CSCL scripts, was developed (Hernández-Leo et al., 2006). *Collage* encourages designers to browse the documentation of different CLFPs and select the pattern most suitable to their particular learning scenarios. The selected CLFP proposes the structure of a CSCL script, which then needs to be refined for the learning scenario. This includes detailing information about concrete roles, time schedule of the session(s), activity contents and resources (Hernández-Leo et al., 2007).

The usage of design patterns has been positively evaluated for CSCL script design, and actually has already been proposed for assessment design (see Mislevy et al., 2003; Delozanne et al., 2006). This paper focuses on the possibility of using assessment and learning patterns together to create complete CSCL scripts, each type of pattern addressing different design problems. In order to facilitate the access to this design approach for non-expert designers, this paper proposes a model for the integration of assessment and learning patterns. The results of the research undertaken will be the basis for the formulation of a complete design process of CSCL scripts, which continues previous efforts in order to include support for assessment design.

Therefore, the rest of the paper is organized as follows. Next section details the scope of the design patterns for assessment proposed here. The following section describes the approach to support and model the application of assessment patterns within CSCL scripts. Then, the evaluation of the proposed approach is presented. The paper concludes with a discussion of the issues tackled in this paper.

Pattern-based design of embedded assessment in CSCL scripts

This section describes the problem of assessment design from the point of view of a pattern-based design approach. Before we discuss this, however, we need to define precisely the type of assessment pattern considered. A complete assessment plan is a complex entity that comprises several aspects. Several works have identified different pieces of information needed to define an assessment plan, such as the knowledge, skills and abilities (KSAs) that are to be assessed; observable variables or indicators; assessment types; or instructions for processing assessment data (Almond, Steinberg and Mislevy, 2002; Joosten-Ten Brinke et al., 2007). Nevertheless, other existing proposals emphasize the fact that, in spite of the mentioned contextual bindings of assessment design, it is possible to extract common assessment processes. These represent different activities or methods of carrying out assessment or delivering it to students. In further detail, it has been argued that there are several aspects that characterize assessment processes (Miao et al., 2007): (a) the description of the involved roles; (b) the definition of the activity types and sequencing; and (c) the description of the document flow.

Capturing configurations of these elements has already been the aim of different pattern-based approaches. For instance, the PADI Project (Mislevy et al., 2003) defines patterns which contain information about the scientific knowledge or skills that are to be measured, the specific observations that are needed to make inferences about that knowledge or skill, and the situations in which such evidence may be obtained. On the other hand, Delozanne et al. (2006) proposes a set of patterns to track students' know-how and strategies in a specific context in problem solving activities. This paper deals with patterns that capture the structure of assessment techniques, focusing on the requirements of CSCL settings. Such structures define different forms of carrying out assessment, in terms of the assessment process or the configuration of a certain aspect of it. Like CLFPs, they propose templates that can be reused and embedded in CSCL scripts. Examples of such techniques exist in the literature. For instance, *peer review* (Dochy, Segers & Sluijsmans, 1999) has been captured as a candidate pattern, describing a process which engages students in assessing their partners' work. Other forms, such as 360º feedback, self assessment, or performance assessment (Joosten-Ten Brinke et al., 2007) can be described in similar terms.

The selection of adequate assessment techniques is critical for their effectiveness in enhancing learning. Due to space limitations, this paper does not deal with the selection of assessment patterns, and is focused only on the integration of the selected assessment patterns with the rest of components of a CSCL script. Scripts themselves typically describe a learning process composed by several phases, activities and groups (Dillenbourg, 2002). Thus, it is necessary to describe how assessment is also part of that process. Sequencing, role assignation and document-flow, which were mentioned before to define the assessment process, are actually features shared between learning and assessment activities. In order to highlight the importance of the interrelationship between learning and assessment, the following section will discuss a form of support for the assembly of learning and assessment patterns to build CSCL scripts.

Assembly of patterns in CSCL scripts

Using several patterns in the creation of a CSCL script, some addressing learning design issues, other tackling the design of the assessment plan, means that the patterns (or, rather, the templates they propose and are applied in the script) have to be *assembled* (Hernández-Leo et al., 2007): the different aspects tackled by the each pattern need to be interrelated, in order to make sure that they are coordinated to achieve certain learning objectives. In other words, learning and assessment patterns can support or complement each other. In order to describe the coordination of assessment and learning patterns, this section discusses a model which structures the information that characterizes the integration of the assessment processes within the CSCL script.

There are some clear relationships between the components of a CSCL script and its assessment plan. First, assessment must address the learning objectives of the script, including those related to collaborative learning (Boud, Cohen & Sampson, 1999); this information should be explicit. Second, assessment embedded in the script occurs at specific moments and involves certain actors. As shown in Figure 1, assessment can be related to the following elements of the script: addressed learning objectives, data source activity (which provides data to carry out assessment) and assessor's activity (which indicates who processes assessment data, and when). Thus, both learning activities (performed by learners) and support ones (carried out by teachers or other staff) can be assessment activities. However, the most important information to characterize assessment is its purpose (Almond, Steinberg & Mislevy, 2002). Thus, we will define three possible purposes (see bottom-right of Figure 1) of the application of assessment patterns within CSCL scripts.

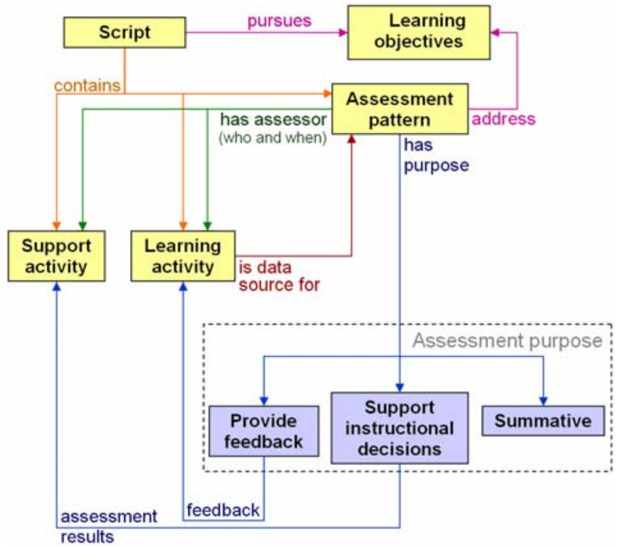

Figure 1. Model for the integration of assessment patterns embedded in CSCL scripts.

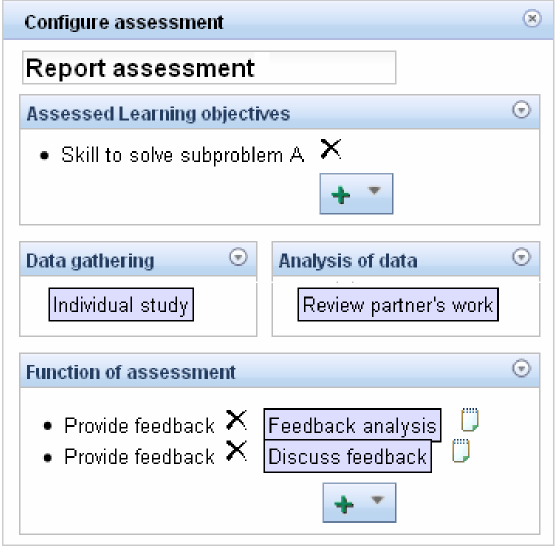

Figure 2. User interface of form for edition of assessment information in Web Collage.

First, assessment can be used for summative purposes, related to attainment decisions dealing with certification of students' achievements (Dochy & McDowell, 1997). Second, assessment can be used to perform monitoring and diagnosis, and thus support instructional decisions, which are related to the changes that the teacher may introduce in the teaching/learning process as it is conducted; adapting instruction during the learning activities, according to assessment results, offers a possibility to enhance learning (Stiggins, 2002). This author also highlights another relevant use of assessment: providing feedback to students, which will be our third possible purpose for assessment. This purpose of assessment deserves special attention. According to Black & Wiliam (1998), feedback is characterized by two actions: First, students must perceive the gap between the expected goal and his/her own actual state; second, they must carry out a remedial action to close the gap. These two actions constitute an important part of the related learning activities. The designer must therefore be aware of two issues: (a) feedback is given out to students in specific activities along the script (i.e., assessment is related to the document flow of the script), and (b) the learning activity will be affected by the delivery of feedback, as shown in Figure 1. Therefore, assessment has a relevant effect on the learning process, which has to be adapted accordingly to these issues.

The model shown in Figure 1 structures the identified relationships between assessment elements and other script components. Making these relationships explicit is intended to increase the designer's awareness of the complexity and importance of integrating assessment elements within a CSCL script. By using the model, the application of assessment patterns in the script can be explicitly defined, at least in terms of the purpose, temporal location of assessment elements, and assignation of assessment-related roles to groups and participants, of each assessment pattern. Moreover, this information is expected to help other actors involved in the life-cycle of CSCL scripts, by documenting the design decisions and the rationale of the script.

In order to enable users to include assessment patterns in these scripts, an extended version of Collage, called Web Collage, was developed. Web Collage allows a designer to assemble CSCL scripts by using learning patterns (CLFPs) and assessment patterns (the current version allows using assessment-centered CLFPs, such as Peer review, and patterns for assessment activities). These patterns define templates of components that can be combined to create complete scripts. Thus, for each assessment pattern, the tool creates the related activities and embeds them in the script. Finally, this tool allows the definition of the information included in the model described in this section, through a form-based interface, shown in Figure 2. Web Collage provides users with graphical representations of the resulting CSCL script, depicting also the position and purpose of applied assessment pattern.

Evaluation

This section describes the evaluation that has been carried out on the approach discussed in this paper. Our objective was to evaluate its adequacy to support non-expert designers in the creation of CSCL script, by promoting the awareness of the importance and facilitating the design of assessment. To this end, we were interested in the perception of such designers concerning the proposed approach. The evaluation was carried out through a case study in the context of a workshop on technology support for the design of collaborative learning scenarios. The workshop, carried out in July of 2008, was attended by 13 university teachers, who are considered to represent the target user for which the proposal is developed: teachers (though only in higher education), non-experts on collaborative learning, but interested in applying both technology and collaboration to their own practice.

The workshop had a length of 8 hours, distributed in two sessions. These included lectures combined with hands-on activities to introduce the attendees to some of the issues behind the design of CSCL scenarios, as well as available technology solutions that can facilitate the design task. The workshop included a central activity consisting on the creation of a CSCL script with Web Collage. In this activity, the participants were not given a pre-assigned design task, but were encouraged to consider a case from their own teaching practice. This allows us to evaluate the usage and perceptions of the participants with respect both to the tool and the proposal.

The data gathered in the workshop can be classified in: questionnaires filled up by participants (at the beginning and the end of each workshop), logs generated by Web Collage, a final discussion between participants and the workshop staff, and observations taken by the staff. Both quantitative and qualitative data were analyzed in order to detect and understand trends in the participants' opinions and perspectives. The analysis of the data was focused on three issues: (a) usability of the tool: since the complexity of use of the application could preclude the expected benefits of the proposal, it was deemed necessary to analyze the intuitiveness and user friendliness of Web Collage; (b) adequacy of the support for the design task: whether the proposed approach facilitates the integration of assessment patterns in CSCL scripts; and (c) adequacy of joint design of learning and assessment: the perceptions of the participants concerning the design process that merges learning and assessment design.

With respect to the usability of Web Collage, the participants valued the tool quantitatively, giving it an overall slightly positive score: 3.31 (value range: 1 (no useful at all) – 5 (most useful), standard deviation 0.85). However, the participants pointed out in their qualitative comments in the final questionnaire several problems with the usage of the tool. It is especially relevant that 4 participants indicated explicitly that introducing assessment patterns is particularly complex. In spite of this, analysis of the logs generated by Web Collage shows that actually users actually were able to introduce a number of patterns: the scripts averaged 1,69 CLFPs per script (deviation: 0,94) and, more importantly, 2,46 assessment patterns (deviation: 1,94). Therefore, the participants were able to select and embed an important number of patterns by using Web Collage, though with high differences in the complexity of the created scripts. However, with respect to the second issue, the adequacy of provided support, we can also note that the participants generally judged that they could not complete the design of assessment: 62 % of participants indicated that their assessment process was left incomplete. It is clear that the model described in the previous section was found exceedingly complex: 4 participants expressed this opinion, versus only one who considered it clear (the rest, 8 participants, did not answer this question, which is also significant).

With respect to the third issue, the adequacy of joint process of designing assessment and learning together, the participants were divided: 4 (31 %) considered they should be done at the same time, while 6 (46 %) affirmed that learning design should precede assessment design. Only one participant chose first assessment design followed by learning design. However, the great majority of the participants agreed that they should appear together in a script (11 participants, 85 %), even though 2 of these were skeptic whether designing them at the same or not had actually any effect. Finally, the majority of participants agreed that assessment and learning are interrelated, and this should be reflected in the design, e.g., providing information about "[…] determining the moments of assessment".

Discussion and conclusions

The objective of this paper has been to discuss some issues around the application of assessment patterns in the creation of CSCL scripts. This is an important problem, and proposing a complete solution is out of the scope of this paper. However, we have focused on a particular issue: the usage of assessment patterns jointly with learning patterns, following the principles of a create-by-reuse framework (Hernández-Leo et al., 2007). Within this context, we have studied the problem of assembly of combinations of patterns in order to create a CSCL script.

This paper argues that there is certain information that can be used to indicate the moment in which assessment is carried out, by whom, the object of assessment and its function in the pedagogical model of the script. This information, structured in the model described in this paper, is relevant both for the designer (in order to configure all the affected elements of the script accordingly), and the users of the script.

This proposed approach has been implemented in a software tool, Web Collage. The tool and approach have been evaluated in a case study which gives inexperienced university teachers the role of CSCL script designers. The evaluation results indicate that the tool itself plays a critical role in the evaluation of the proposals, as several usage problems were identified by the users. With respect to this, the case study provides valuable feedback to improve the tool. Despite these issues, the case study indicates that the proposed approaches described here can enhance assessment design. The participants were able to create the structure of CSCL scripts assembled by several patterns, including assessment ones, and valued positively having assessment information embedded in the scripts.

However, the difficulties found in the evaluation indicate that the proposal cannot be expected to be used by inexperienced designers in its current form. One factor that affects this is the lack of guidance in Web Collage with respect to the needed tasks to complete a design. Future work is aimed at developing a detailed design process and its implementation in Web Collage, in order to provide further guidelines to non-expert designers; this is intended to overcome the complexity of the usage of assessment and learning patterns together, while at the same time keeping the advantages of pattern-based design. Finally, our objective is to integrate different tasks in a single design process, including the selection of patterns (which is done through a pattern language, not described here due to space limitations) and the refinement of patterns, which was not discussed in this paper either.

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Sustainable Script and Scaffold Development for Collaboration on Varying Web Content: The S-COL Technological Approach

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Abstract: We present a single solution for the following two problems: (1) to provide just-in-time support for collaborative learning tasks on top of arbitrary web pages (e. g. in order to foster online search competence) and (2) to transfer collaboration scripts implemented on a particular platform to other platforms. S-COL solves both by using fixed browser-side scripts and scaffolds and triggering them by recognizing types of functionally equivalent web pages, and combines this with collaborative web-browsing.

Two seemingly unrelated problems and current attempts at solutions

Collaborative learning tasks involving authentic web content may require support on top of existing web pages that cannot be anticipated by instructional designers. For example, collaborative search tasks for fostering online search competence will lead groups of learners to a broad variety of different web pages. Several approaches to support learners during online search tasks have been developed. One is to provide search engines developed specifically for particular target groups (e. g. children) that closely resemble general search engines, but restrict results to information appropriate for their target group, such as „Yahooligans!“ (now „Yahoo! KIDS“; see Bilal, 2002), or sophisticated search environments enriched with tools that help users organize their search activities, such as „ARTEMIS“ (Wallace et al., 1998). However, these tools are not so much directed at increasing the learners' competence, but rather at permanently decreasing task difficulty. Furthermore, while rather unsupported search tasks, including WebQuests (Ikpeze & Boyd, 2007), may be insufficient for increasing learners' online search competence, so-called "guided pages" developed specifically for a particular learning tasks (Berry, 1998) are both less authentic and not transferrable to different learning tasks.

A more promising approach to foster online search competence could be collaborative online search, which has been demonstrated to have beneficial effects on the strategies employed, although not yet on learning (Lazonder, 1995). Beneficial effects on the acquisition of online search competence might be expected from collaboration scripts that structure learners' interactions in the various phases of a collaborative online search task (cf. Kollar, Fischer & Hesse, 2006). On the cognitive and instructional side, this approach requires the identification of a set of general strategies of (collaborative) online search that can be applied to and accordingly should be prompted during the interaction with a broad variety of thematically diverse web pages. Although we addressed this topic in an ongoing research project, we will not pursue this issue here. On the technical side, support for the application of these strategies in different phases of a collaborative online search task has to be provided in the context of the web page currently displayed, based on some idea of where the learners are in the search process. Tools for changing existing web pages for display in a browser (e. g. enriching them with script prompts) have already been developed (e. g. Greasemonkey, 2009). The main problem, however, is to determine automatically, which script prompts should be displayed along with a specific web page encountered by the learners. Accordingly, a desideratum for supporting online search activities would be a tool to implement collaboration scripts with specific prompts for the different stages of collaborative online search tasks.

In this paper we argue that the technical solution to this problem also constitutes the missing jigsaw piece in a solution for a further problem that has received substantial attention by CSCL researchers in recent years: the re-use of collaboration scripts on different learning platforms. Typically collaboration scripts, e. g. for online discussion, have been implemented and tested as part and parcel of particular learning platforms (e. g. Stegmann, Weinberger & Fischer, 2007). This approach makes the investigation of the generalizability of findings across learning environments as well as broad use of empirically evaluated collaboration scripts rather difficult. To overcome these problems, several proposals have been made. A prominent approach is the development of a common script language or a unified framework for the description of scripts such as the one developed by the European Research Team "CoSSICLE": This framework (Kobbe et al., 2007) defines a small number of components and mechanisms of computer-supported collaboration scripts. The components are participants, activities, roles, resources, and groups; the mechanisms comprise task distribution, group formation, and sequencing. On the basis of this descriptive framework a graphical modelling tool for the development of new collaboration scripts was built (Harrer & Malzahn, 2006). As an output, this modelling tool produces an IMS-LD file, i.e. a file that can be read by all learning platforms that support the IMS Global Learning Consortium Standards. However, currently we are not aware of any free available learning platform that supports this "dialect" of IMS-LD and accordingly can import a script description as an IMS-LD file.

Another, more practitioner-oriented approach is the "manyscripts" approach (Dillenbourg & Hong, 2008): The manyscripts tool offers teachers an environment to adapt a set of specific scripts with regard to their own needs, especially their own learning material. At the moment only the Concept Grid, Argue Graph, and Ice (Dillenbourg & Hong, 2008) are available. The manyscripts environment is a standalone learning platform. A native integration into other learning platforms has not been a goal and is thus not supported yet.

Currently, neither the common script language and graphical modelling approach nor the manyscripts approach are suitable to develop new scripts and implement them in a broad range of different learning environments. A framework that effectively supports the re-usability of technology-based collaboration scripts is currently not available. The transfer of scripts from one learning environment to another is still hampered by the need to adapt and integrate the collaboration script into the new learning platform. Therefore, a solution for using scripts developed and evaluated in one learning environment on other platforms is also still a desideratum. If different learning platforms are considered as varying web content, this problem becomes a special case of the problem of the development of scripts for learning activities involving varying web content. In the next section, we will present a comprehensive solution for this problem.

A comprehensive solution

The basic idea

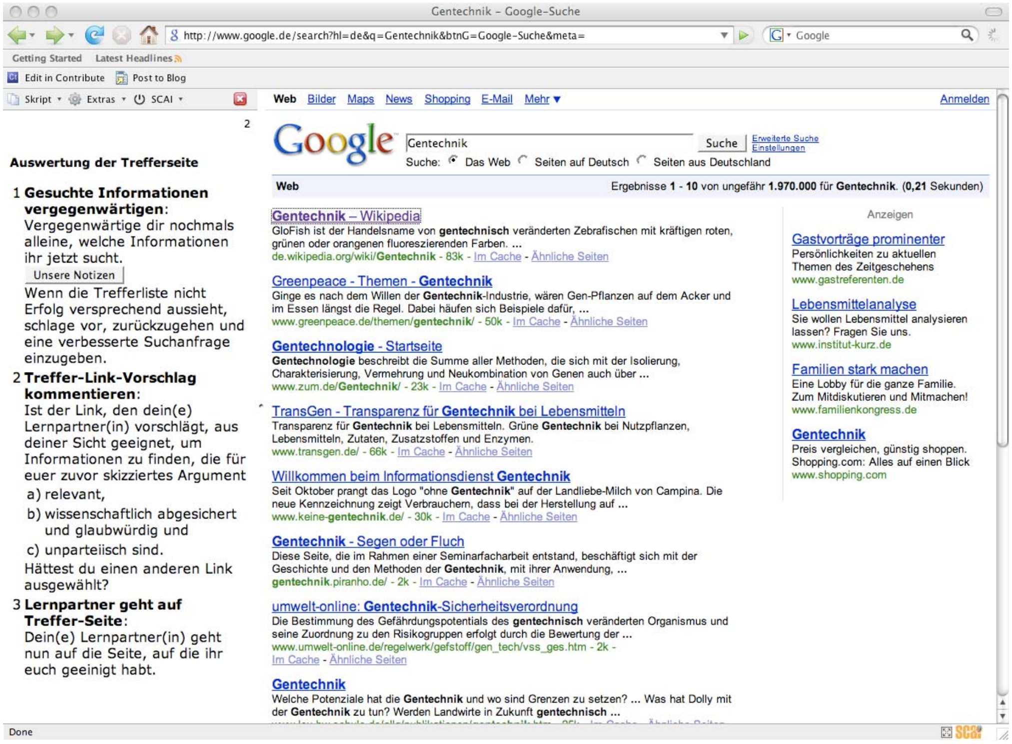
In an interdisciplinary collaboration involving educational psychologists and computer scientists, our goal was to develop a tool that provides a common solution for the two problems described by providing content- and role-specific support for collaborative learning tasks to each individual learner. The basic idea to achieve this goal is very simple: Rather than trying to enrich pre-selected web-pages with scaffolds or embed scripts into particular learning platforms, our approach endows *the browser* with instructional support by means of a library of hard-coded scripts and scaffolds that are invoked based on the recognition of functionally equivalent web pages or components of different collaborative learning platforms. Therefore we regard this as a kind of two-fold "Copernican Turn" in sustainable script and scaffold development. We will now describe this approach in more detail using the scenarios of the two problems described before as examples.

Practically any search engine such as Google, Yahoo! or Live Search consists of a form for entering a search query that leads to a series of results pages with a common structure. From here, the user can reach the web pages that may contain the information he or she is looking for. Accordingly, there are three types of functionally equivalent pages users have to traverse whatever web search engine they use: the search query form, the results page, and the pages reached from the results page. The first two of these page types usually have a structure of functionally equivalent elements that is typically identical across different search engines: For example, a search query form usually contains one (or sometimes several) text field(s) for entering the search terms and a button for starting the query. As each of these page types corresponds to a specific phase during an online search, specific cognitive processes that may require support are associated with each type of page. For example, while a user is on the search query form, he or she needs to generate a set of search terms yielding relevant results and precluding irrelevant results. At the results page, hits need to be selected based on an evaluation of the information provided along with them. At the pages reached from there, search strategies have to be applied to locate relevant information on the website. Based on this correspondence between the types of pages traversed during an online search and the cognitive processes required in different phases of the search, the capacity of recognizing these page types and their component objects allows for the development of scaffolds that are specific for each site type, but apply to any web search engine that has this kind of structure.

This solution can be transferred to the problem of re-usable collaboration scripts for online discussion. In our own prior research (e. g. Stegmann, Weinberger & Fischer, 2007) a script for the construction of single arguments was implemented in an online discussion board of a collaborative learning environment by means of prompts and separate text boxes for the parts of an elaborated argument. These were embedded in the form for entering messages and their contents were composed to one continuous message before posting the contribution. Thus, the collaboration scripts were part and parcel of the learning platform itself. Our new approach takes advantage of the fact that any discussion board contains functionally equivalent parts such as the form for entering contributions, which usually consists of separate fields for the message and its title as well as a button for posting the message. If a component of the browser manages to recognize this *type* of form as well as its aforementioned component objects, the collaboration script does not have to be implemented in the discussion board itself, but can be embedded in the browser. The prompts and text boxes described above can be displayed in a separate area of the browser window, and the contents of the single text boxes can be composed and sent to the message field when posting the message. The advantage of this approach lies in the fact that it allows for the use of a library of hard-coded collaboration scripts contained in the browser that can be used with a broad variety of web-based collaboration tools. This solution works for any kind of "micro" script that applies to a single component page of a collaborative learning environment. As our solution for implementing re-usable collaboration scripts can also navigate automatically to different component pages of a collaborative learning environment, it also allows for the implementation of guidance for larger sequences of learning activities in "macro" scripts.

Main features of S-COL

We now turn to the specification of these ideas in the S-COL (Scripting for Collaborative Online Learning) technological approach, which provided the basis for the implementation in the tool we developed to solve the two interconnected problems described before.



<u>Figure 1</u> The S-COL graphical user interface with the implementation of a collaboration script for supporting collaborative online search.

The graphical user interface

As mentioned before, the tool was implemented as a browser plug-in. Accordingly, the main part of its graphical user interface is the browser itself. The area of the browser used for displaying web pages is split in two parts (see figure 1). The area on the right hand side is called the "browsing area". It exhibits exactly the same behaviour as a standard web browser: It can present HTML pages, and the user can navigate through them by using links and menu elements of the browser such as the home, forward, and backward buttons. The part on the left hand side is called the "scaffolding area". Its size is flexibly adaptable both by the user dragging its border as well as by JavaScript functions. Furthermore, it can be invoked and hidden by a function key. Its content can be flexibly designed using HTML. The content of the scaffolding area (text boxes, buttons etc.) can "interact" with objects in the browsing area. For instance, information from the browsing area such as the content of tables and text boxes or the URL of the actually displayed Webpage can be read out. Furthermore, the browsing area can be manipulated by posting text into forms, activating buttons or even by navigating to an arbitrary URL. The scaffolding area moreover contains a menu bar providing functionalities such as loading scripts or scaffolds and configuring the navigation behaviour of the tool (see below).

Tool functions

This section describes the functions of the S-COL tool. For each function first the behaviour of the tool is characterized, then the methods for achieving this behaviour are described.

Content- and role-specific support. The display of content- and role-specific support for learners collaborating with this tool requires the recognition of types of web pages and their component objects. For example, to support the writing of arguments, a script needs the information whether the current page is a page for the composition of a new message or not. Based on this, scaffolds and scripts are displayed in the scaffolding area of the tool.

The recognition of the pages is achieved by means of a template file that contains a description of each variant of every page type as well as its components. To identify a page type, both the URL and the Document Object Model (DOM) of the page can be used. For example, it can contain the URL of the Google variant of the search query form to identify this page as the page type “search query form”, and the XPath expression or the ID of the text box for the search terms to identify the text box on the Google search query form as this type of object. It can contain the same information for other search engines as well as similar information for the other page types traversed during an online search. Based on the information contained in the template file, a JavaScript function yields the type of the page currently displayed. Using the values returned by this function (and potentially also the assigned role of the person using the computer), the contents of the scaffolding area are selected by JavaScript code contained in the HTML file loaded into the scaffolding area. Thereby, the contents of the scaffolding area can be adapted in a content-specific way according to the type of web page recognized, and in a role-specific way according to the role a person may have been assigned before. This includes that the scaffolding area can be configured to disappear if no scripts or scaffolds should by provided.

Collaborative web browsing. The tool furthermore allows for collaborative web browsing. This is to say that all learners belonging to the same group can automatically see the same web pages in their browser. The assignment to groups is done via a dialog window for group formation. Each participant of a group has the opportunity to navigate the whole group to a different web page by simply using his or her browser the usual way, i. e. by clicking on links, menu elements, or entering a new URL. This brings the page he or she navigates to on the screen of all members of the group. If a learner opens a new tab, new tabs will be opened in all connected browsers.

The collaborative web browsing function can be adapted in several ways. In principle, each user can dissociate him- or herself from collaborative web browsing. This comprises an active and a passive component: On the one hand, a user may switch off the function that “sends” his or her navigation actions to the other group members. This has the effect that his or her navigation actions have no effects on what is displayed on the computer screens of the other members of the group, so he or she can no longer “lead” the group to other pages. On the other hand, he or she may switch off the function that “receives” the navigation actions of the other group members. This has the effect that navigation actions of other group members have no effects on what is displayed on the respective group member’s computer screen, so he or she no longer “follows” other group members to other pages. S-COL also offers a JavaScript function that allows script developers to switch these communication functions on and off. Furthermore, the rights to switch on and off the “sending” and “receiving” of navigation actions can be set globally to allow teachers to control their students’ options during collaborative learning tasks on the Internet.

The collaborative web browsing function is based on JavaScript functions that send messages to all group members as well as to all connected web browsers with activated S-COL plug-in. These messages can also be used to synchronize the scaffolds. These messages could also be used for a chat tool implemented in the scaffolding area.

Administration

Group settings. The tool contains a dialog window for the formation of groups that also allows to assign roles to individual members of the groups and to select scripts and scaffolds from the library to be displayed in the scaffolding area for individual users. This window is password-protected and can be used from each connected browser to change the group-related settings of any of the connected users.

Script and scaffold library. Furthermore, S-COL has a library that contains the different scripts and scaffolds that can be invoked in the scaffolding area. Currently this is implemented as a folder that contains all the files with the contents of the scaffolding area as well as the JavaScript code for adaptation and talking to the contents of the browsing area. For the future, we plan to either develop or integrate a script and scaffold editor. This will allow for easy configuration of the template file used for the recognition of site types and the organization of page types, subtypes and their component objects. It will also simplify the assignment of script prompts and scaffolds to page types and subtypes as well as roles and also states of counters to implement the fading of scripts or scaffolds based on the number of occasions the students have experienced to practice certain skills.

Further potentials, limitations and open problems

In this contribution we suggested an approach to the development of flexible and reusable collaboration scripts and scaffolds that draws on earlier conceptual and empirical research on scripts, but makes a big step forward by changing perspectives on the problem. While we think that S-COL is already a very helpful tool for research on technology-supported collaboration scripts, we are also quite sure that it has much more potential. As described above, important steps have been made with respect towards a common script language (cf. Harrer & Malzahn, 2006). An implementation of an interpreter of this IMS-LD based language in S-COL would allow the graphical modelling of new scripts *and* their broad application in many web-based learning environments. Subsequently, the transfer of successful collaboration as well as systematic research on collaboration scripts would be much easier to conduct. Also approaches like “manyscripts” (Dillenbourg & Hong, 2008) could be integrated into the scaffolding area of S-COL. Thereby, the tool may bridge the gap between the development of new technology-based collaboration scripts and their systematic application in research and practice.

In the wake of the features of S-COL that allow for an easy implementation of collaboration scripts, several additional functions to support research were developed. For example, if it is necessary to analyze the search activities of learners, usually screen recordings have to be analysed. S-COL can log the browsing behaviour including all clicks, mouse movements, and the content (i.e. the DOM) of all web pages visited. S-COL may also help to transfer identification data from pre-test to post-test in field studies, even without awareness of the participants, thereby reducing the likelihood of mistakes and data loss. Furthermore, the tool can be used to administer process measurements (e. g. for flow experiences) by the Experience Sampling Method (ESM) during learning activities: By a JavaScript function using the communication functions of S-COL each connected browser can be individually asked to open a short questionnaire in a pop-up window.

Some limitations and open issues also have to be discussed. The main limitation is the restriction to HTML-based learning environments. A growing share of learning platforms implement Java- or Flash-based communication tools. These tools can hardly be scaffolded with S-COL. Besides, the possibility of the logging of all user events including the DOM also has its dangers: S-COL could easily be configured to trace all web activities of a user and to send this data to a specified server somewhere on the web. However, an S-COL version without unsafe tracing functions can easily be derived from the current version.

While these issues still need to be addressed and there is still further potential to be actualized by connecting S-COL to previous achievements in script and scaffold development, S-COL has probably been a major breakthrough in sustainable script and also scaffold development for changing web-content.

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Enhancing pair learning of pupils with cognitive disabilities: Structural support with help of Floor Control

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Abstract: Computer-supported collaborative learning has the potential to be an effective learning method for pupils with cognitive disabilities, but there is just little research in this area. A computer-supported environment offers several possibilities to handle the specific demands of this target group, for example, by structuring the learning situation with *Floor Control*. *Floor Control* explicitly structures the activities in the learning environment and implicitly enhances communication. To examine whether the *Floor Control* supports the collaboration process on activity level as well as on communication level or not, two versions of a CSCL environment were realized and compared with each other. The results revealed an improved task-related communication and a higher quality of learning results.

Introduction

Collaborative learning (CL) and computer-supported collaborative learning (CSCL) can be effective learning methods (Slavin, 1996), even for pupils with cognitive disabilities (McDonnell, Thorson, Allen, & Mathot-Buckner, 2000; Wishart, Willis, Cebula, & Pitcairn, 2007). But there are just a few systematic studies about CSCL with pupils with cognitive disabilities (Lingnau, Zentel, & Cress, 2007). Accordingly, there exists little guidance for designing a CSCL learning environment and, thereby, structuring the communication and the learning activities of this target group.

The current paper focuses on the question how to use a CSCL environment to promote pair learning of pupils with cognitive disabilities. Building on theoretical and empirical insights from CSCL research in special education, a CSCL environment was developed. The study presented in this paper considered the effect of *Floor Control* on structuring communication and, thereby, collaboration of the target group.

First, we consider the specific characteristics of the target group and the resulting demands on a CSCL environment. Furthermore, we point out how *Floor Control* can support collaborative learning of pupils with cognitive disabilities. Afterwards, we introduce our research design and the results of our study. We finish with discussion about the experiences and results.

Designing a CSCL environment for pupils with cognitive disabilities

The challenge in supporting pupils with cognitive disabilities is the variability in manifestations, genesis and development of their abilities. Besides deficient cognitive abilities, restricted communication abilities are a common criterion among pupils with cognitive disabilities (Sondersorge, 1972). Difficulties in communication abilities apply to the organisation of speech (e.g. turn-taking, Sacks, Schegloff, & Jefferson, 1974), to formal particularities (e.g., time-structure, Wagner-Willi, 2001), to understanding, to speaking (Hensle & Vernooij, 2002), and to reading abilities (Conners, 2003).

Wishart et al. (2007) were the first who investigated the effect of collaboration on the core cognitive skills of pupils with cognitive disabilities. In specific, they considered the ability to sort by caterogy. They remark that "one partner with intellectual disabilities often dominated verbal exchange" (p. 370).

This dominating behaviour in communication was also found in the effort ratio. Lingnau and colleagues (2007) showed that the higher attaining pupil of a learning pair did two thirds of the overall action in collaboratively solving a puzzle even if both pupils have had the abilities to solve the puzzle on their own.

The restricted communication and coordination abilities make it necessary to support the collaboration process of pupils with cognitive disabilities. Aim of the support should be twofold: (1) achieving a balanced effort in collaboration and (2) fostering task-related communication. By structuring the collaboration with the help of the environment, the cognitive resources of the pupils are disburdened so that they can be more focussed on the content of the task. An adequate method to structuring in the background is the *Floor Control* design (Lingnau et al., 2007).

Implicit scripting of communication by Floor Control

As we know from different studies, communication can be influenced by the environment. For example, Suthers and Hundhausen (2003) verified that communication of collaborative partners can be implicitly fostered by the design of an external knowledge representation. Similarly, we expected that *Floor Control* can foster communication by explicitly structuring coordinative activities. *Floor Control* coordinates the simultaneous use of shared resources in a collaborative setting. At a particular time, one pupil is authorized to act with the shared resources. So to speak this pupil has the floor. For pupils with cognitive disabilities, it is important to assign a specified proceeding in order to avoid additional coordinative activities rather than learning activities. Therefore, we chose to implement a confirmation tool. The floor was reassigned when the pupils agreed or repeatedly disagreed. When having the floor the respective pupil was responsible for the shared resources. The other pupil could only affect the actions in the shared resources by communicating about the problem solving. When only disagreeing with the floor holder, this could provoke communication on his side. We would speak of *implicit scripting* (Runde, Bromme, & Jucks, 2007) of communication by explicitly scripting the activities in the shared workspace.

Research questions

The presented study aimed at investigating the following research questions.

(1) How far does the *Floor Control* Design affect the *acting* of both pupils in the shared workspace? Is it possible to balance the actions of the pupils in the shared workspace?

(2) How far does the *Floor Control* Design affect the *communication* of the pupils?

(2.1) Does the *Floor Control* Design cause task-related communication aiming at *controlling* the action of the floor holder?

(2.2) Does the *Floor Control* Design cause task-related *arguing* about declined objects?

(2.3) Does the *Floor Control* Design minimize the *coordinative* communication of the pupils?

(3) How far does the *Floor Control* Design enhance the *quality* of the collaborative learning?

Method

We designed a CSCL environment (Lingnau & Bientzle, in press). The software development is done by using FreeStyler (Hoppe & Gassner, 2002), an open and modular simulation and modeling tool. This environment was aligned to the needs of pupils with cognitive disabilities, e.g. the whole learning environment is not constrained by scripture. To examine whether the *Floor Control* design can support the collaboration process of pupils with cognitive disabilities or not, two version of the environment were realised and compared with each other.

Sample and design

Thirty-five pupils of a school for cognitive disabled children in Tübingen (Germany) took part in this study. The pupils were at the age of 12 to 17. To ensure coping with the demand of the task, preconditions for participating in the study like basic physical, cognitive, socio-emotional, and communication abilities as well as capability to concentrate on the task, were collected. Therefore, a pre-diagnostics concerning the abilities of the pupils were conducted at the beginning of the study. Out of the 35 pupils, 20 met the preconditions and were combined in learning pairs. The Floor Control condition was compared with a control condition with equal rights to act with the shared resources at any time. The pairs were randomly assigned to one of the two conditions.

Learning task and learning environment

The collaborative task based on the furniture task (Wishart et al., 2007). In our CSCL setting the task follows the idea of a jigsaw design. The learning pairs were seated in the same room and each pupil got an own tablet pc. The pair got several symbols of furniture and other things that they had to assign to the adequate room of the house represented in the shared workspace. The task started with one symbol in one of the private workspaces. Thus, the respective pupil first had to move this symbol from the private workspace into the shared workspace. To show the ownership of the symbol, it got the colour assigned to the pupil before the task started.

In the *Floor Control condition*, only this pupil had the right to move the symbol from room to room. After confirming the position of the symbol, the non-owner got the right to confirm or decline the position but was not allowed to move the symbol in the shared workspace. Consequently, the only way to affect the position of the symbol was arguing with the other pupil about the position. When agreeing on the placement or when disagreeing several times, the next symbol appeared in one of the private workspaces randomly selected.

In the *Control condition*, the pupils had the same rights at any time with exception of moving a symbol from the private workspace into the shared one. So pupils also had to agree on the placement of a symbol via the confirmation tool, but they both could move all symbols in the shared workspace. Consequently, pupils had two possibilities to coordinate their actions: On the one hand, they could argue with one another and, on the other hand, they could move a symbol to the room they thought to be adequate. The possibility to act simultaneous in the shared workspace demands coordinative skills from the pupils that could otherwise be used for task-related exploration.

<u>Graphical material</u>

The house was presented as a schematic and two-dimensional image. The rooms of the house were labelled as kitchen, bedroom, living room, bath room, children’s room, dining room, and workroom. The symbols that the pupils should assign to the rooms were taken from Widgit Software™ (German Version 2.061). Some of these symbols were introduced to the pupils before data collection.

Procedure

Pupils took part in three sessions on three different days. The setting will be explained in the following.

Session 1: Introduction. In the first session, the pupils were informed about the area "furnishing" within their classes. First, they worked with a three-dimensional model of a house. Then the labels of the rooms and the *standard symbols* were introduced. Afterwards, the assignment to the adequate rooms was trained. In the next step, they transferred the learned knowledge to a two-dimensional schematic representation of the house, analogue to the image used in the virtual environment. Aim of this introduction session was that pupils got to know the experimenter and became familiar with the task and the symbols. This was important because pupils with cognitive disabilities have difficulties to handle with unknown people and new situations. Besides this, the session was used to inform about the schedule of the study.

Session 2: Pre-diagnostics. In the second session, the pre-diagnostics were collected. First the core cognitive skills to sort by category were individually tested (following the blocksorting task used by Wishart et al., 2007). Second, the class teachers were interviewed about the physical, cognitive, socio-emotional, and communication abilities as well as learning behaviour of their pupils. Therefore, we used a questionnaire based on Heidelberger Kompetenz Inventar (Holtz, Eberle, Hillig, & Marker, 2005) and Vineland Social Maturity Scale (Doll, 1965).

Session 3: Core study. The core study began with the refreshment of the labelling of the rooms. Afterwards, the learning environment was introduced by collaboratively solving a categorisation task. The experimenter supported the understanding concerning the handling of CSCL environment while a pair coped with the learning environment. Subsequently, the furniture task was collaboratively accomplished. In this phase, the experimenter had only intervened when technical problems occurred.

Dependent measures

Actions. All actions in the shared workspace were automatically logged during the furniture task. In specific, the following actions were logged: moving a symbol in the shared workspace, declining the position of a symbol, and confirmed position of the symbols.

Communication. To investigate the communication the pupils were videotaped. The communication acts were coded in order to investigate our research questions. The following communication acts were categorized and compared with the overall communication acts:

- Task-related communication aiming at controlling action (e.g., "Put the bed in the bedroom.")
- Coordinative communication (e.g., "It's your turn.")

In addition, communication acts after every declining the position of a symbol were coded in whether they consist of arguing or not (in the following called task-related arguing after declining).

Quality of collaborative learning. The quality was assessed by counting accurate positions of the symbols.

Results

Pre-diagnostics

The investigation of the child characteristics shows that *Floor Control* condition and control condition conditions are comparable in all categories (see table 1).

Table 1: Pre-diagnostics of abilities

	Floor Control condition ∑	**Control condition** ∑
Categorisation	118	126
Communication	226	217
Cooperation	223	222
Socio-emotional	133	135
Learning behaviour	136	137

Research question 1: How far does the Floor Control Design affect the *acting* of both pupils in the shared workspace?

First, we were interested in whether the *Floor Control* Design balanced the actions of the pupils in the shared workspace. We expected that in the *Floor Control* condition both pupils reveal similar amounts of moving and rejecting symbols in the shared workspace because *Floor Control* equally distributes action possibilities among the pupils. Therefore, we considered the distribution of the moving and rejecting actions between pupil 1 and pupil 2 in the shared workspace. The descriptive statistics shows that there is no difference in the distribution between both conditions (see table 2).

Table 2: Distribution of the moving and rejecting actions between pupil 1 and pupil 2

Pair	Floor Control condition	Control condition
1	9 : 4	18 : 14
2	9 : 9	0 : 0
3	10 : 9	57 : 32
4	15 : 7	21 : 10
5	25 : 11	50 : 17
Ø	13.6 : 8	29.2 : 14.6

Research question 2: How far does the Floor Control Design affect the *communication* of the pupils?

Second, we were interested in whether the *Floor Control* Design affects communication. We expected that the proportion of task-related communication aiming at *controlling* action on the overall communication acts is enhanced by *Floor Control*. In contrast, the proportion of *coordinative* communication on the overall communication acts should be reduced by *Floor Control*. And that is exactly what we found. Pupils in the *Floor Control* condition revealed 14 percent task-related communication aiming at *controlling* action, whereas pupils in the control condition revealed only 7.5 percent. In contrast, pupils in the control condition showed 34 percent *coordinative* communication, whereas pupils in the *Floor Control* condition showed only 14 percent.

Moreover, we expected that the proportion of task-related arguing after declining is higher in the *Floor c*ontrol condition. As expected, pupils in the *Floor Control* condition revealed 82.3 percent arguing after a decline has taken place, whereas pupils in the control condition revealed only 48.8 percent.

Research question 3: How far does the Floor Control Design enhance the *quality* of the collaborative learning?

Third, we were interested in whether the *Floor Control* Design enhances the quality of collaborative learning. We expected that *Floor Control* improves the quality of the task solution by structuring acting and communicating. As expected, pupils in the *Floor Control* condition placed more symbols in the accurate room than pupils in the control condition (*Floor Control*: $M = 28$, $SD = 1.7$; *Control*: $M = 26.4$; $SD = 7.3$).

Discussion

Overall, the *Floor Control* design affected communication of pupils with cognitive disabilities as well as the quality of their learning results. Against our expectations, *Floor Control* did not balance the activities in the shared workspace.

Concerning the activities, the overall moves were lower in the *Floor Control* condition than in the control condition. This is not surprising because in the *Floor Control* condition the right to move the symbols was restricted to the floor holder. Although the logged actions revealed no more balanced participation of the pupils in the *Floor Control* condition than in the control condition, we found hints that more balance in the *Floor Control c*ondition: In the majorities of pairs, the higher attaining pupil revealed more task-related communication acts aiming at controlling action. This explains the unbalanced moves because the lower attaining pupil reacted to the controlling of the higher attaining pupil in making more moves. This counter-balanced effect could not be observed in the control condition.

The results of the study point out that the *Floor Control* design allows to structure the collaboration process of pupils with cognitive disabilities because it can reduce coordination in favour of task-related communication. However, there are some limitations of the presented study. First, the sample size is rather low. This is especially problematic because the sample is a very heterogeneous one. Consequently, the results should be replicated in further studies. Second, two pairs revealed no communication. But this is rather unproblematic because they were equally distributed among the conditions. Nevertheless the pre-diagnostic should be tighter in further studies. Third, because of the small sample size it was not possible in any case to match pupils according to their abilities, although this was proposed by the results of Wishart and colleagues (2007). Nevertheless, we found a strong effect so that this effect should even stronger when pairing higher attaining pupils with lower attaining pupils more systematically.

The pairing of higher and lower attaining pupils is then especially important when the *Floor Control* design is implemented for learning new stuff and not only practicing. Then the higher attaining pupil is structured in his teacher role and the lower attaining pupil can profit from content-related guidance. Moreover, we would expect that a computer-mediated communication instead of a face-to-face communication enhances the effects of the *Floor Control* design because non-verbal communication is excluded. In the current design, pupils could use gestures to underline their intentions. These gestures have to be substituted with communication acts.

Conclusion

The presented study is the first that implemented *Floor Control* in a CSCL environment for pupils with cognitive disabilities. The aim was to explicitly structure the activities in the shared workspace and, thereby, to also foster task-related communication. By communicating more about the task, the quality of learning should be enhanced. As expected, *Floor Control* can improve communication and learning quality of this target group. Further studies would be helpful to elaborate the applicability of *Floor Control* to support learning of pupils with cognitive disabilities.

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A Practice Scaffolding Interactive Platform

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Abstract. A *Practice Scaffolding Interactive Platform* (PracSIP) is a social learning platform which supports students in collaborative project based learning by simulating a professional practice. A PracSIP puts the core tools of the simulated practice at the students' disposal, it organizes collaboration, structures the students' activity, and interactively supports subject learning. A PracSIP facilitates students' development of complex competencies, and at the same time it supports the students' development of skills defined in the curriculum. The paper introduces the concept, presents the theoretical foundations, and gives an example of a PracSIP.

Epistemic Frames and Epistemic Games: Simulating *Practicum*

In their book *Situated learning* Jean Lave and Etienne Wenger (1991) developed the concept *Community of practice*, which was later to be subjected to further scrutiny by Wenger (2008/1998). A community of practice is a group of individuals participating in communal activity, and continuously creating their shared identity through engaging in and contributing to the practices of their communities and thereby developing a shared repertoire (Wenger, 2008).

David W. Shaffer has worked with the concept in relation to computer based learning. He argues that different communities develop different epistemic frames, that is "[…] different ways of knowing, of deciding what is worth knowing, and of adding to the collective body of knowledge and understanding of community" (Shaffer, 2006, p. 10). Shaffer argues that well established professions like those of doctors, engineers, journalists, etc., each have a particular learning practice, or *practicum*. By simulating such a practicum an *epistemic game* makes it possible for students to learn to *think like* doctors, engineers, journalists, etc. That is, they learn to be a part of a particular community of practice.

Hatfield and Shaffer (2006) define an epistemic game as consisting of "an *activity structure* (the things players do) and a computer-based *epistemic game engine* (the technology players use) which together simulate the process by which adults become fluent in a particular professional practice" (Hatfield & Shaffer, 2006). The examples given of epistemic games are often tools to support a certain subdivision of the practice. To give an example, *Byline* (Hatfield & Shaffer, 2006) supports writing newspaper articles in a certain way, but does not support the interviewing done before writing the article. Nor does the definition imply that an epistemic game engine organizes the collaboration of the players or structures their activities. The organization of the collaboration and activities might be the teachers' challenge; or it might be a task for the students themselves to find out how to act in the game setting.

Practice Scaffolding Interactive Platforms: Simulating *Practice*

A *Practice Scaffolding Interactive Platform* (abbreviated PracSIP) is a game engine or, in my words, an *interactive platform* which is intended to *scaffold* the full *practice*, and therefore includes tools for organizing collaboration and structuring students' activities.

A PracSIP makes students able to simulate (parts of) the community of practice of a professional setting, and thereby helps them develop competencies which are important from an educational point of view. The case presented in this paper is a simulation of (parts of) the community of practice in a newspaper editorial office. *The Editorial Office* (in Danish: *Redaktionen*) is a PracSIP developed by the Danish newspaper *Ekstra Bladet*. The PracSIP builds on a concept paper written by the author of this paper in 2006. It supports many of the activities in a journalist's practice, such as collaboration, planning, research, writing and layout. The students write and layout a newspaper which is then send to a printing office and printed in 4 or 8 pages in color in 1000 copies on real newsprint.

The activity that develops around a PracSIP has a lot in common with project based learning (PBL). PBL is a constructivist pedagogic approach that attaches importance to the student's autonomous interdisciplinary and collaborative work with the subject matter. There is evidence that project based learning can be successful and promote students deep and long-lasting learning (Barron, Schwartz, Vye, Moore, Petrosino, Zech et al., 1998, p. 272f.).

But project based learning is not without problems: "[…] projects offer many attractive promises, but they are often difficult to implement" (Barron et al., 1998, p. 306; cf. Bundsgaard, 2005, ch. 5.3.4.3 and 10.1.4.5). The challenges can be summarized thus: 1) the challenge of chaotic social contexts (organization of collaboration), 2) the challenges of what to do next (structure of activity sequences), and 3) the challenge of promoting subject learning central to curriculum standards (support of subject learning).

Some of the reasons for the challenges can be explained by taking a closer look into the theory of communities of practice. Etienne Wenger states three principles which characterize a community of practice. The members are bound together into a social entity through *mutual engagement*. Members are engaged in actions whose meaning they negotiate continuously. *Joint negotiated enterprise* is the participants' "negotiated response to their situation [which] thus belongs to them in a very profound sense, in spite of all the forces and influences that are beyond their control" (Wenger, 2008, p. 77). The participants have a *shared repertoire of resources*: Words, ways of doing things, routines, actions, artifacts, styles, etc. (Wenger, 2008, p. 83).

The last principle states that the participants have a shared repertoire of rules, steps in a process, knowledge of hierarchies, etc., which are often tacit and inscribed in the practice. Participants in a community of practice know the organization of practice; i.e. they know the rules of *what* shall, must or can be done by *whom*, at *what time*, *where* and *how* in relation to *whom*.

When newcomers are introduced in the community, they get to know the shared repertoire by interacting with more experienced participants as *legitimate peripheral participants* (Lave & Wenger, 1991). But in a community of practice solely consisting of one more or less experienced participant (the teacher) and a number of newcomers, the repertoire of collaboration rules, communication strategies, process steps, etc., has to be introduced in other ways; preferably when it is needed by the individual newcomers, and in a way that makes the process run smoothly. When this fails, the social context is in danger of being chaotic, and the newcomers (the students) have problems finding out what to do next.

For that reason the repertoire has to be more explicit, *reified*, when all participants are newcomers, but it still has to be presented in a way that does not overwhelm the students, making it difficult for them to figure out when to employ which parts of the repertoire. In more complex cases students therefore have to be supported as well in their collaboration as in their individual activity. A PracSIP therefore is an interactive platform that scaffolds both the students' organization of collaboration and helps structure their activity.

Parts of the repertoire (like artifacts, vocabulary, styles) require the students to be capable of doing, knowing, and handling. And some of these activities are central to the curriculum. A PracSIP therefore also integrates support of the students' development of subject related competencies. Shaffer argues that epistemic frames help students see the world in a variety of ways, which are well aligned with the core skills, habits, and understandings of a postindustrial society (Shaffer, 2005). This argument is convincing, but some parts of an epistemic frame might be more relevant in an educational context than others. And some epistemic frames might make it possible to develop more generally relevant competencies. A journalism PracSIP, for instance, can support students in developing their competence of writing, which can be used in many other contexts. The design objectives therefore always have to be double. The developers of a PracSIP must analyze the structure of a reproductive practice (Shaffer, 2005), that is the epistemic frame of a profession, but they must also consider which parts of the profession that demand the most important competencies, and finally they must consider how to support the pedagogical practice to minimize chaos, and support student activity. These triple objectives are equally important, but not necessarily in line with what a professional himself would consider important, when developing a PracSIP.

A central function in *The Editorial Office*, seen from an educational point of view, is the commentary tool which is intended to support and organize commenting on the first draft of the article. The reason for this tool is double. First it is a way of assuring better and more thoroughly revised texts in the final paper. And secondly it is a way of focusing on writing to improve the students writing competence and their reflections on their own and other students' writing. From a journalistic point of view the tool is less important – on a newspaper the practice of giving article critique is often placed after the article has been printed. If the intention of the platform was only to simulate a journalism community of practice, the tool should have been left out. But the central role of writing in the simulated practice as well as in the formal curriculum necessitates focus on students' writing competencies, and makes possible that they practice and reflect on writing in a context where they recognize the importance of producing a well-structured and well-formulated text that lives up to the genre and stylistic demands of a newspaper article.

The core design principles of a PracSIP can be summed up thus: A PracSIP facilitates simulation of dimensions of an authentic community of practice, scaffolds the practice by organizing collaboration, structuring activities, and giving access to the core tools of the community of practice, and it supports development of competencies which can be transfered to other situations.

These design principles appear to be in line with the four principles of design that Barron et al. (1998) propose, and which "can lead to doing with understanding rather than doing for the sake of doing" (Barron et al., 1998, p. 273). These principles are: 1) learning-appropriate goals, 2) scaffolds that support both student and teacher learning, 3) frequent opportunities for formative self-assessment and revision, and 4) social organization that promotes participation and result in a sense of agency (ibid.). The design principles are explicated in the following four sections.

Authentic practice

Shaffer and Resnick (1998) has conducted a meta-analysis of literature on authenticity in education. They found that the term was used in a number of different ways, each describing important aspects of authenticity, but all left out important aspects. Shaffer and Resnick therefore introduce the integrating term *thick authenticity*, which

> [...] refers to activities that are personally meaningful, connected to important and interesting aspects of the world beyond the classroom, grounded in a systematic approach to thinking about problems and issues, and which provide for evaluation that is meaningfully related to the topics and methods being studied (Shaffer & Resnick, 1998, p. 203).

In this paper the term is used in this sense, but the importance of social relations is added as a fifth principle. On the one hand there are internal social relations. Participants in an authentic practice do not do the same work at the same time, but work together by performing different parts of the task, and by being dependent on the work carried out by each other. On the other hand there are external social relations. Engaging in authentic work means to produce something that someone else is supposed to use, consume, or comment on. That is, it is an important aspect of authenticity that it involves social relations between the students and someone outside the classroom, e.g., parents, politicians, peers, etc. *Authenticity is authentic communication situations*.

Scaffolding

The term scaffolding was introduced by Wood, Bruner & Ross in 1976.

> This scaffolding consists essentially of the adult “controlling” those elements of the task that are initially beyond the learner’s capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence. The task thus proceeds to a successful conclusion (Wood, Bruner & Ross, 1976, p. 90).

In this initial conception the concept was used to describe cooperation on well-defined simple tasks where a parent or a teacher helps a child. The term has been used in a wide area of other contexts, and the extension of the use can be taken even further by talking about scaffolding of collaboration, and scaffolding of individual and collective activity sequences. *The PracSIP thus scaffolds practice*. Below it is argued that it meets the demands of the three components of the scaffolding framework that Roy Pea points out (Pea, 2004, p. 431f.): 1) *Fading*: It must become possible for the learner to do without the scaffold through the use of the scaffold. 2) *Channeling* and *focusing*: The scaffold can consist of reduction of the degrees of freedom for the learner to direct him on the task. And 3) *modeling*: The scaffold can be carried out by modeling more advanced solutions to the task.

Organizing collaboration

In a community of practice mutual engagement among other things find expression through hierarchies, collaboration, and agreements on how to get the job done, how to divide the responsibility, etc. In a simulated community of practice which consists of newcomers, these organizational challenges might be too overwhelming (cf. Bundsgaard, 2005). A PracSIP includes tools to organize the collaboration, e.g. by organizing distribution of roles and responsibilities or by organizing time, deadlines, communication, etc.

In *The Editorial Office* it is done by supporting the distribution of students in different editorial offices, and by a time planning and task distribution tool (producing a simple Gantt chart). The planner (see Figure 1) helps the students decide on which articles to write, who has the responsibility of each subtask (researching, taking photos, writing, layout, etc.), and when each subtask has its deadline. The students are supposed to continuously indicate on the status bar which article and subtask they are working on or have finished.

Thereby the students have the possibility of being aware what their current assignment is, and when they are supposed to be finished. And their teacher has access to an overview of the students’ progress.

Structuring activity sequences

The *shared repertoire of resources* is a cornerstone of a community of practice. One important resource is knowledge of sequences in which activities are supposed to be carried out, and knowledge of dependencies between activities. E.g., you don’t layout an article before it is finished and revised.

In *The Editorial Office* a number of activity sequences are *channeled*. The overall sequence of planning, researching, focusing, writing, and layout is reproduced in the order of the menu points. For example when launching their newspaper project, the students start by deciding which kind of newspaper they want. This *profile tool* makes it easier for the students to create a more whole newspaper. When they have decided on the newspaper's profile they proceed to the aforementioned *planning tool*, then they are led further to the research phase, etc. The phases are not cut in stone; the students can jump back and forth between them, but the structure helps the students remember to distribute their tasks, do the research, get the articles revised, etc.

The process of writing and revising an article is also structured by the PracSIP. When the student thinks his article is finished, he saves it and is then asked to change the status of the article by choosing from a list of possible values, the first after 'being prepared' being 'ready for comments' and the last one being 'ready for layout'. The article does not occur in the layout tool before it has been assigned the status 'ready for layout'. The PracSIP thereby impose a certain sequence of activities, but to avoid making the system to in-flexible, it is possible to skip some of the steps in the sequence. This can be seen as a way of *fading* the PracSIP when the students have learned to organize their sequence of activities themselves.

Figure 1. Planner.

Tools

The *shared repertoire of resources* is much more than the structures of activities. Wenger explains it in this way:

> The repertoire of a community of practice includes routines, words, tools, ways of doing things, stories, gestures, symbols, genres, actions, or concepts that the community has produced or adopted in the course of its existence, and which have become part of its practice (Wenger, 2008, p. 83).

Some of these resources are to hand in a typical school practice (journalists and students use paper, pens, tables, chairs, etc.), others are peripheral to the practice as it is simulated in a school setting, and some must be made available either by the teacher or by the PracSIP.

The Editorial Office includes a wide variety of tools from the world of journalism: photo editor, photo stock, notepad, mind map tool, text editor, and a graphical layout tool, and it includes some tools especially developed for the simulation, such as the aforementioned profile and commentary tools, the planner, and a number of videos and integrated explanations of tools and activities.

Each phase opens with a short video concerning the specific phase. A journalist, an editor, a photographer, etc., talks about the core aspects of the work done in the phase, and communicates some of the core words and concepts to be used in the process. The journalist for example talks about journalistic approaches, the "Hey, You, See and So" model and about objectivity. By working as journalists, photographers, editors, etc., the students immediately use the words, and find themselves in situations like those they have heard about, and thereby the explicit wordings, the roles, and the activities get more embodied and tacit, than if they were just explicitly explained.

Subject learning

Simulating a community of practice is a way of improving motivation and of supporting students' development of multiple epistemic frames. But this might be viewed as secondary to the development of transferable more or less basic skills and knowledge. Often the resources developed in a community of practice build on knowledge and skills which can be seen as very relevant from a curriculum point of view. A PracSIP therefore also supports the students' development of skills and knowledge that are relevant to them.

This can be done through integration of *interactive assistants*, a concept of computer assisted learning which is introduced in Bundsgaard, 2005 (ch. 5.3.3). An interactive assistant is a computer program which guides the students through a complex problem. An interactive assistant builds on a description of an academic area, method or problem, or a core task in the community of practice; it integrates the student's project, sets the scene for the student (and not the computer) to do the thinking, and collects the input of the student in an overview that the student may print and discuss with the teacher and other students, and use in his or her further work. In *The Editorial Office* there are more than 40 such interactive assistants.

To give a short example, the interactive assistant, which helps prepare an interview, starts out by asking the student to write a brain storm on what he wants to find out; then it goes on displaying the students' brain storm, presenting a short explanation of the difference between open and closed questions, and asking him to write up three open questions and three closed questions. On the following page the student's open questions is displayed, and the student is asked what he imagines the interviewee would answer to the open questions, and he is asked which follow-up questions he could then ask. On the last page the interactive assistant shows a summery of the input, and thereby offers an interview guide to the student, which he can discuss with his teacher, and use when he conducts the interview.

Conclusion

A Practice Scaffolding Interactive Platform (a *PracSIP*) is an artifact, a tool informed by practice, a transformation of resources from tacit structures to explicit structures. It is not a simulator as is a flight simulator, because it does not graphically simulate a world or a person's point of view. It is a tool used by people in *their* simulation of a practice. The PracSIP organizes and structures the participants' practice and thereby scaffolds their learning.

The Editorial Office has been on line one and a half year by now, nearly 8000 students have produced around 600 newspapers, 600.000 copies have been printed. Responses from both teachers and students has been positive and enthusiastic. An electronic survey carried out for *Ekstra Bladet* (Pedersen 2009) showed that 75% of the students (n=182) think that *The Editorial Office* is good or very good (8% find it bad or very bad), and 98% of the teachers (n=97) consider *The Editorial Office* as good or very good. 57% of the students describe them selves as much more or little more active than in 'normal teaching'.

When asked about their judgment of the students' learning outcome, 95% of the teachers (n=96) evaluate their students' academic development as satisfying or very satisfying (42%), and 69% of teachers (n=96) say that the academic level is appropriate. 25% find it hard (1% find it too hard) (Pedersen 2009).

These numbers are very encouraging and clearly support the theoretical deliberations above, but the knowledge of students' learning outcome of working with *The Editorial Office* is still too uncertain. Therefore future research will focus on developing methods to describe the learning outcome of PracSIPs.

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A technical framework to support implicit structured collaboration

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Abstract: Verbal communication, particularly the ability to give directions and understand them, is a key not only for learning but also for every day life. Since one main objective of schools for pupils with cognitive disability or learning difficulties is to prepare pupils to manage their every day life on their own, we expect that teaching pupils how to learn and work collaboratively by sharing tasks, give directions to each other and understand them, will support this process and provide them in becoming more independent. In this paper we will present an environment which supports implicit scripted collaborative task solving without increasing cognitive load.

Introduction

There are only few systematic studies about the potential of collaborative learning for pupils with cognitive disabilities. Wishart, Willis, Cebula, & Pitcairn (2007) showed that collaborative learning can be an effective learning method for this target group. In general computers can be used as effective learning tools to support pupils with cognitive disabilities in acquisition of basic learning skills (Zentel, Opfermann, & Krehwinkel, 2007) and help them to increase self-determination, independence, and integration skills (Cosden, et.al, 1990; Wehmeyer, 1998).

We started with a preliminary study (Lingnau, Zentel, & Cress, 2007) using a collaborative software environment with a shared workspace where two pupils had to solve a puzzle task. This task was designed similar to a problem solving task for early learners described in (Lingnau, Hoppe, & Mannhaupt, 2003) where two pupils had to write words in a shared workspace. Lingnau, et. al. implemented a jigsaw design where one pupil owned the consonants while the other owned the vowels. In our setting puzzle pieces had to be moved to the correct position but without any restrictions which objects may be manipulated by a user and how one could agree or disagree to the co-learners' actions within the workspace.

As a side effect for this basic CSCL setting we observed that not only the higher performing pupil took the leadership and started to give directions to the other learner but that also the lower performing pupil backed off from being an active and mindful contributor. Since the pupils had to act by turns the lower performing pupil mostly just added one of his/her puzzle pieces from the private repository to a random position in the shared workspace or moved a piece to a random but wrong position in the workspace. The higher performing pupil waited his/her turn and undid this action by moving the piece to either the correct position or just outside the working area. Analysing the results of our preliminary study we started to develop a more elaborated environment which aimed at providing a shared workspaces where access to objects could be restricted to to objects' owner and where the approach of scripting tasks for collaborative learning (Fischer, Mandl, Haake, & Kollar, 2007) could be implemented.

In this paper we will present the technical environment which has been developed to be used for further studies to explore whether we can stimulate collaboration and/or accomplish and foster communication between learners with cognitive disabilities or learning difficulties.

Designing the Framework

The implementation is based on FreeStyler (Hoppe, & Gassner, 2002), an open and modular simulation and modelling tool which already provides a collaborative workspace in a replicated architecture. Evaluating the results of our preliminary study and from a non computerised collaborative task described in Wishart, Willis, Cebula, & Pitcairn (2007) we concluded that a modified environment should provide the possibility to define scripted tasks without specifying a fixed interaction pattern but giving pupils the freedom to operate with their existing ability to communicate and interact. Furthermore we wanted to avoid the decrease of motivation and the increase of cognitive load caused by an explicit collaboration script.

From our preliminary study we learned that mechanisms are necessary to prevent lower performing pupils from backing off and leaving the task solution to the higher performing pupils. In the first setting the pupils had to take turns but could manipulate every object in the shared workspace. The implementation of a floor control mechanism seemed to be essential for an improvement of the task.

To avoid that the target group of pupils with cognitive disabilities has to handle to much activities at the same time we limited the number of objects the learner has to deal with. Thus, we implemented a confirmation mechanism where both pupils had to validate the final position of an object in the shared workspace (Margaritis, Avouris, & Kahrimanis, 2006) in combination with floor control. The floor control mechanism was realised as a switch. A new object is assigned to one of the learners and the ownership is represented by different colours. Instead of having an explicit moderator controlling the task, this is done implicitly when the learner who owns an object confirms the position where he wants the object to be placed. Thereby the other learner now has to either confirm or decline the decision which means he is implicitly ask by the system what he thinks about the suggestion. By getting the confirm or decline buttons enabled this is an implicit information for the learner that he/she gets the floor and it is his/her turn now.

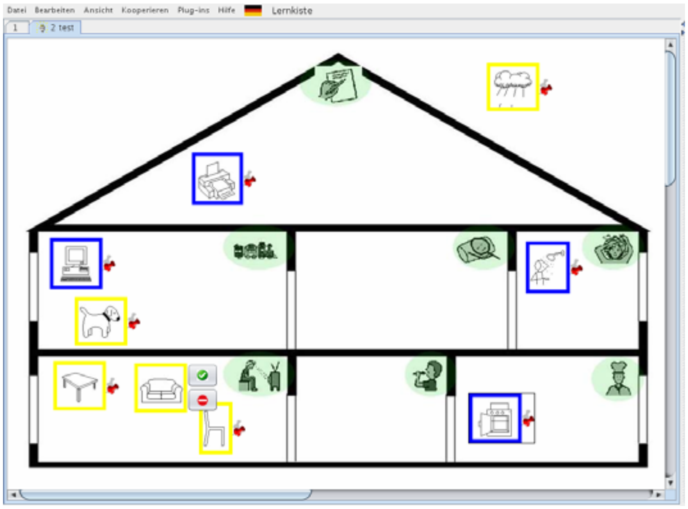


Figure 1. Collaborative workspace with floor control and confirmation tool.

Not before both learner confirm the position of an object the next object appears in the private workspace of one of the learner. Figure 1 shows the collaborative workspace with floor control and confirmation tool. There are already few objects sorted into the corresponding rooms in the house and fixed by confirmation from both learners. The sofa in the living room is the object which has to be placed next. In figure 1 the owner of the object has already confirmed the location and by doing so the confirmation and decline buttons appeared to the other learner. A detailed description of the steps is given below.

Collaborative learning environments per se do not guarantee that interaction in collaboration will be maximised or at least increased. Collazos, Guerrero, Pino, Ochoa, & Stahl (2007) showed exemplary that if certain design aspects are taken into account the likelihood that interaction takes place can be increased. As a result they propose a design model which grounds on three coherent parts. The *initial condition* defines the setting under which collaboration shall take place. In our case we want pupils with cognitive disabilities which do not have strong communication skills to work together on a sorting task.

In the model of Collazos, et. al the initial conditions are constituting the possibilities of structuring the collaboration. Therefore it is not sufficient to instruct the learners with a collaboration task. The expected collaboration process must directly refer to the task itself, to the roles assigned to the learners, to the environment in which the learner is acting and to the resources provided to the learners.

In our case the main goal is to stimulate communication and interaction between pupils with cognitive disabilities which are normally unaccustomed to solve tasks in pairs and without intervention of non disabled people. From our preliminary study we learned that although we directed the pupils to take turn and try to contribute in a meaningful way the pupils did not behave as expected. Even more then normal learners it is likely that pupils with cognitive disabilities will not be able to follow the rules at any time, even if they are observed by a teacher. In addition it is also even more likely that learners do not understand directions given to follow a script or they need to concentrate too much on the directions instead on the task.

In our preliminary study either of the learners usually overtook the leadership, even if both pupils where able to solve the task on their own. This minimised communication and one of the pupils often just acted by chance when he/she had turn and the other pupil solved the task on his/her own. These results point out that many pupils with cognitive disabilities have difficulties to coordinate learning activities in a collaborative situation on their own. The restricted communication and coordination abilities make it necessary and reasonable to support the collaboration process of pupils with cognitive disabilities with technology. With our floor control and confirmation tool approach we try to avoid an unnecessary increase of cognitive load by guiding the pupils through the task with an implicit script but without changing or restricting the pupils' familiar way of communication.

The new software environment had to be designed in a way which allows the implementation of an implicit script to structure the learners' activity and contribution and help them to organise and coordinate the solution finding process. The software achieves a balanced effort in collaboration and foster task-related communication. By structuring the collaboration with the help of the environment, the cognitive resources of the pupils are disburdened so that they can be more focused on the content of the task.

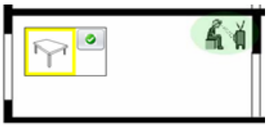
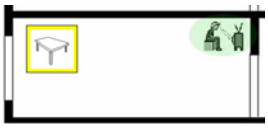
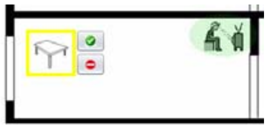
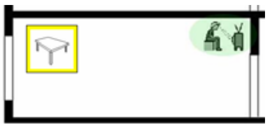
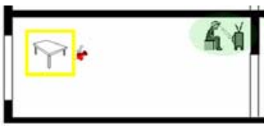
The software environment

As a result of the requirements we detected the collaborative workspace of FreeStyler has been enhanced by two features: floor control and a confirmation tool. Although FreeStyler provides collaboration between unlimited workspaces in our case we decided to design the floor control and confirmation functionality for just two learner. An expansion for more learner is foreseen but currently not yet done.

To visualise the ownership of objects within the floor control mode every learner has his/her own colour. The background of the private workspace, where new objects appear for the first time, is coloured with the learners assigned colour and after he/she has dragged an object from his/her private workspace into the shared workspace it appears with a frame in the learners' colour.

In the floor control mode, objects can only be moved by the owner of an object as long as he/she did not confirm the position of an object. Table 1 shows the different steps the learner are going through while they are working on one object. In step 1, the owner of an object (learner 1) has positioned a new object in the shared workspace. It has a coloured frame representing the ownership of learner 1. In this step, the object can only be moved by learner 1 since he is the owner an has the floor for this particular object. If learner 2 wants learner 1 to move the object to another position he/she has to tell him/her what he/she wants since there is no possibility for the non-owner to manipulate the object.

Table 1: Step by step visualisation of the floor control procedure.

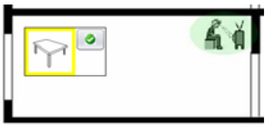
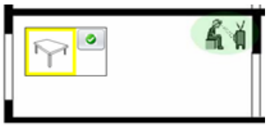
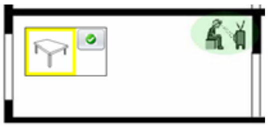
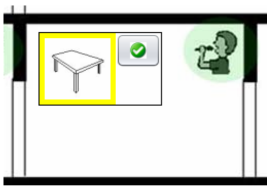
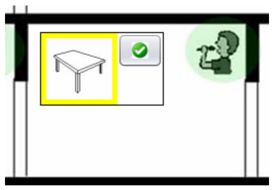
	Learner 1 (object owner)	Learner 2
1	Learner 1 dragged a new object from his private into the shared workspace and has to confirm the position.	
	 Object movable	 Object locked
2	Learner 1 confirmed the position. Now learner 2 must either agree or decline the decision.	
	 Object locked	 Object locked
3A	Learner 2 declined the decision of learner 1. This led back to step 1.	
	 Object movable	 Object locked
3B	Learner 2 agreed with the decision of learner 1. Now this object is fixed and the next object appears by chance in one of the learners private workspaces.	
	 Object fixed	 Object fixed

When the owner decides that the object shall stay at a certain position he/she confirms the position by pressing the check button. After that, he/she cannot move the object any more and learner 2 gets the buttons to either confirm the decision or decline it. Since learner 1 still has the floor the only possibility for learner 2 to change the objects position is to decline the decision of learner 1 and communicate where he/she wants the object to be moved to. Step 3A shows the situation after learner 2 has declined the decision of learner 1. Now learner 1 can again manipulate the object and when he/she is sure about the position he/she can press the check button once again to ask for confirmation by learner 2. After an optional number of unsuccessful tries the system assumes that the learners are unable to agree on a position and the object is removed from the shared workspace.

When learner 2 confirms the position (step 3B) the object is finally fixed which is visualised by a thumbnail. Now either the other learner or a randomly selected learner gets the next object in his/her private workspace and can drag it into the shared workspace. The possibility of having only one active object at a time is optional but for pupils with cognitive disabilities it guarantees that they concentrate on only one object and do not loose the focus. To provide control group settings for evaluation purpose and data ascertainment in studies the confirmation feature can be used without using floor control. In this second setting the different steps to find a joint solution vary for the two learner.

In Table 2 the different steps of this modified setting are visualised. In step 1, learner 1 has moved a new object from his/her private workspace into the shared workspace. Again, the colour of the frame represents the owner of the object in the shared workspace. But in this setting without floor control both pupils can move the object around and confirm the position of the object if they wish to do so. In step 2 learner 1 has already confirmed the position of the object which means he/she cannot move the object any more and learner 2 now can either confirm the position as well or move the object to another position. By moving the object, learner 2 declines the decision of learner 1 to fix the object and both pupils have to confirm the new position again, as shown in step 3A. If also learner 2 confirms the position by pressing the check button, the object will be fixed as shown in step 3B.

Table 2: Step by step visualisation of the confirmation process without floor control.

	Learner 1 (yellow)	Learner 2 (blue)
1	Learner 1 dragged a new object from his private into the shared workspace. Both learner can now move the object around and have to confirm the final positon.	
	 Object movable	 Object movable
2	Learner 1 confirmed the position of the object as final. Now learner 2 has either to agree or he can move the objects if he wants to decline the decision.	
	 Object locked	 Object movable
3A	Learner 2 declined the decision by moving the object to another position. This leads back to step 1.	
	 Object movable	 Object movable
3B	Learner 2 agreed to the decision of learner 1.	
	 Object fixed	 Object fixed

Conclusion and Outlook

The design process of the collaborative floor control environment has been mainly influenced by the preliminary study and further hypothesis. Thus, a more elaborated study Bientzle, Wodziki, Lingnau, A., & Cress, U (2009) has been done where learners from a German school for pupils with cognitive disabilities worked in pairs on a collaborative task. For this study we adapted the furniture task, which has been successfully applied by Wishart, et. al. (2007) in a non computerised collaborative learning scenario with pupils with intellectual disabilities. In the computerised scenario, using our floor control and confirmation tool environment, the pupils were placed in a face-to-face situation using pen-based interactive screens in front of each learner. Figure 2 shows the screen of one learner from a pair working on the furniture task. Further information and results can be found on Bientzle, et al. (2009).

Figure 2. Collaborative workspace with floor control and confirmation tool

As postulated by Collazos et al., we believe our environment can be used to define tasks which will increase communication and collaboration between learners with cognitive disabilities. The results of our second study revealed an improved task-related communication and a higher quality of learning results. The floor control design allows for implicitly structure the collaboration process of pupils with cognitive disabilities because it reduces coordination in support of task-related communication. Thus also other learners, e.g. with learning difficulties or special educational needs, might benefit from implicit scripting when working on collaborative tasks.

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Representational Scripting Effects on Group Performance

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Abstract: This study investigated the effects of a tool designed for supporting the online collaborative performance of learners carrying out complex learning tasks. Appropriate collaborative cognitive activities may be evoked by structuring the whole learning task into phases and providing congruent external representations for each stage (i.e., representational scripting). It was hypothesized that this combination would lead to increased individual learning and better results for the collaborative task. In groups, 47 secondary education students worked on a complex business-economics problem in four experimental conditions, namely one where groups received task-congruent representations for all stages and three where they received one of the representations for all three phases (task-incongruent). The results indicate that groups that received task-congruent representations in a phased order scored higher on the collaborative task, though this did not result in increased individual learning.

Introduction

Research on computer-supported collaborative learning (CSCL) has shown that computer technology can provide support (i.e., tools) for students collaboratively carrying out complex learning tasks. In such tasks, groups of students often solve a problem performing different kinds of activities in two dialogue ‘spaces’, namely a *content space* using cognitive activities for coping with the part-tasks / solution phases such as orienting to the problem (i.e., exploring the problem space), finding solutions and evaluating the solutions, and a *relational space* using communicative activities such as making knowledge and ideas explicit, creating shared understanding and negotiating multiple perspectives (Barron, 2003). Usually, the support consists of (1) externalizing knowledge and ideas through chat and representation tools to provide a solid basis for the negotiation of meaning (Fisher, Bruhn, Gräsel, & Mandl, 2002), (2) providing scaffolding opportunities through structuring the learning process via scripting modules and the representational guidance of a tool (Reiser, 2004, Suthers, 1998), and (3) offering offloading possibilities - by providing external memory (i.e., storing previous contributions and constructed external representations) and external information sources which leave more working memory left for the negotiation of meaning (e.g., Hollan, Hutchins, & Kirsh, 2000). Although we acknowledge the value of these studies, we question whether the full potential of computer technology can be reached by such an approach. Solely studying the effects of a tool aimed at supporting the whole learning task provides only one perspective on the problem, neglecting supporting the task demands and activities of part-tasks which may be so ontologically divergent that they need different tools to properly deal with them (de Jong et al., 1998). Furthermore, such an approach does not take combining and integrating the benefits of multiple tools into account. This may be especially detrimental when students are coping with all task demands and activities required for collaboratively carrying out complex learning tasks. First, students - typically non-experts - experience representational difficulties when carrying out such learning tasks (Chi, Glaser, & Rees, 1982). Students are often not able to create and apply suited problem representations which hinders them during problem solving. Second, grouping students does not spontaneously lead to discourse that is beneficial for learning (Dillenbourg, 1999). Due to the complexity of these learning tasks, students need to be supported in (1) performing the specific task demands and activities of the part-tasks in a proper sequence, (2) acquiring and applying well-suited problem representations for each part-task, and (3) combining different problem representations (Ploetzner, Fehse, Kneser, & Spada, 1999; Spector, 2008; van Merriënboer, Kester, & Paas, 2006). By combining the advantages of a scripting module together with a representation module - *representational scripting* - proper collaborative cognitive activities can be evoked.

Representational Scripting

The tool scripts problem-solving behavior by explicating and sequencing different part-tasks in the problem-solving process with the goal of evoking the creation and application of specific problem representations. The tool’s *scripting module* structures the learning task by dividing it into a sequence of ontologically distinct problem-phases (i.e., problem orientation, problem solutions, solution evaluation) so that they can be foreseen with representations congruent with the task demands and activities required for each phase (Duffy, Dueber, & Hawley, 1998; van Bruggen, Boshuizen, & Kirschner, 2003). In the *problem orientation phase* students should start by constructing a cognitive bridge between their initial mental model and the mental model to be created

(Chi et al., 1982; Jonassen, 2003). This phase focuses on constructing a global problem representation, becoming aware of the problem itself and of the important concepts of the knowledge domain along with the constraints and criteria for solution and evaluation. For creating such a problem overview, a qualitative problem representation is more appropriate than a quantitative one (Jackson, Stratford, Krajcik, & Soloway, 1996; White, & Frederiksen, 1990). Qualitative representations provide an overview of the relevant concepts in the knowledge domain, supporting students in broadening the problem space. When the relationships are also quantitatively specified, as is often the case in business economics where these tools are being developed, students are more restricted in creating a suited problem representation because their attention is more focused on specific concepts and their mathematical relationship. This may be detrimental for problem solving because it hinders them in finding multiple solutions. The *problem solutions phase* aims at applying the underlying principles of the knowledge domain to produce concrete solutions. This phase is more structured and focuses on combining the concepts of the domain into principles and explicating causal relationships between the problem and the proposed solutions. This enables students to reason about the advantages and disadvantages of the proposed solutions. The main advantage of these activities is that the solutions come in a rather straightforward, often causal, way from this which makes the problem solving process more efficient and effective (Chi et al.) The problem representation remains qualitative, but contains - along with the central concepts of the problem - causal information that supports students in finding multiple solutions to the problem. During the *solution evaluation phase* it is more appropriate that students relate the solutions and their consequences with the purpose of negotiating their suitability. These discussions should enable them to reach a final and suitable problem solution. This part-task focuses on simulating the proposed solutions and gaining insight into their quantitative effects. It can only be understood if the students have a well developed qualitative understanding of the knowledge domain.

The *representation module* visualizes the knowledge domain by providing external representations (ERs) that influence cognitive behavior through their representational guidance (Cox, 1999; Suthers, 1998). Due to its ontology (i.e., objects, relations, and rules for combining them) each ER offers a restricted view of the domain making it easier to express certain aspects of that domain (Green, & Petre, 1996; van Bruggen et al., 2003). By matching the representational guidance of the ERs with the phase-related part-tasks, students' understanding of the knowledge domain should gradually increase. However, an ER is seldom effective for all task demands and activities; a specific ER guides performance on a certain part-task (Cox, & Brna, 1995). Complex learning tasks require students to create different problem representations, which necessitates receiving multiple ERs that support them in creating these representations. Although it is important to distinguish the different phases and their required representations (Lesgold, 1998; Ploetzner et al., 1999), some studies indicate that combining multiple ERs requires extra cognitive activity which can be detrimental for learning. The extra cognitive burden hinders students in mastering all ERs and forces them to stick to just one ER and thereby one kind of reasoning (Boshuizen, & van de Wiel, 1998). The difficulties students encounter in combining multiple ERs are often due to (1) problems translating from and coordinating between different kinds of representations (Ainsworth, Bibby, & Wood, 2002), and (2) incongruence between representation and phase-specific (part-)task (Buckingham Shum, MacLean, Bellotti, & Hammond, 1997). Table 1 shows how the representational guidance of a specific ER matches with task demands and activities of a specific problem phase (i.e., scripting of the different ERs).

The *representational guidance* of an ER is determined by its ontology, which is specified through its constraints and salience (see Table 1). *Constraints* refers to what is expressed in the ER: the concepts and their interrelationships (i.e., specificity), and how accurately they are represented (i.e., their precision). *Salience* refers to the differences in expressiveness, caused by the different constraints, and which leads to the determination of the number and types of inferences that can be made. Less specific and less precise ERs have the advantage of having a high processability (Larkin, & Simon, 1987) making it easy to make many inferences from them (i.e., elaboration). Those ERs guide students in elaborating on the concepts of the knowledge domain and in relating them to the problem (Jonassen, 2003). Simple ERs, however, do not have much expressive power (Cox, 1999); the inferences cannot be very detailed. The *order* of an ER (White, & Frederiksen, 1990) determines in what way students can reason about the knowledge domain, determining the quality of the inferences. A *zero order* ER supports reasoning about the concepts and relating this reasoning to the problem in qualitative way. A *first order* ER is more expressive and supports reasoning about causal relationships and guides discussion about possible solutions. A *second order* ER is the most expressive and guides quantitative inference-making which should enable negotiation of suitability of the proposed solutions. When the representational guidance of the ER is congruent with the ontological demands of the part-task of a problem phase, students are supported in performing the required task demands and activities of this phase. A mismatch, on the other hand, means that the ER is incongruent with the part-task. Reasons for this could be that the ER is too simple because it contains only global information, or too complex because students do not have enough prior domain knowledge to grasp and make use of the complexity of the ER.

Table 1: Congruence between external representations and task demands.

Problem phase	ER	Representational guidance			
		Constraints		Salience	
		Specificity	Precision	Order	Elaboration
Problem orientation	Conceptual	Low	Undirected relations	Zero	Unstructured
Problem solutions	Causal	Middle	Causal directed relations	First	Quasi-structured
Solution evaluation	Simulation	High	Model directed relations	Second	Structured

Research Focus

This study focuses on how the design of a tool that scripts problem-solving behavior through providing ontological distinct external representations affects both individual and group performance on task performance and learning. Due to the presumed match between ERs and part-tasks, students' conceptual understanding should gradually increase, making it easier for them to solve current and future problems in the knowledge domain.

Design and Expectations

Learning groups were required to solve a case-based problem in business-economics. All experimental groups had to collaboratively solve the problem in three problem phases. To this end, ERs and part-tasks were either matched or mismatched to the phase. In three mismatch conditions, groups received a different ER (i.e., conceptual, causal or simulation ER) which matched only one of the part-tasks (i.e., problem orientation, problem solutions, solution evaluation, respectively). Here, the scripting module structured the collaboration process in three phases, but only one of the ERs is available (phase-mismatch). In the fourth condition, groups receive all three ERs in a phased order receiving the ER most suited to each problem phase (i.e., there is a match between ERs and part-tasks for all phases). Groups in this condition receive the complete array of representations in the representation module of the tool. We hypothesize that the students in the match condition *(H1)* create a better developed conceptual understanding (i.e., learning gains) and *(H2)* will arrive at a better solution to the problem (i.e., task performance), because their knowledge has progressively evolved from qualitative to quantitative.

Method

Participants

Participants were students from one business-economics class from a secondary vocational education school in the Netherlands. The total sample consisted of 47 students (27 male, 20 female). The mean age of the students was 16.67 years ($SD = .80$, $Min = 15$, $Max = 18$). Students were randomly assigned to 15 triads and 1 dyad, which were equally divided between the four experimental conditions.

Learning task and materials

CSCL-environment: Virtual Collaborative Research Institute

Students collaborated in a CSCL environment called *Virtual Collaborative Research Institute* (VCRI, see Figure 1), a groupware application for supporting the collaborative performance of complex learning tasks, inquiry tasks and research projects (Jaspers, Broeken, & Erkens, 2005). For this study, six tools that are part of the VCRI were used and, except the *Note*s *tool*, shared among group members. The *chat tool* is used for enabling synchronous communication, supporting students in externalizing and discussing their ideas and knowledge. The chat history is stored automatically and can be re-read. Students can read the description of the learning task and the different part-tasks and other information sources (e.g., formula list) in the *Assignment menu*. The *Co-writer* is a shared text-processer supporting students in formulating and revising their answers to the part-tasks. The *Notes tool* is an individual notepad intended for cognitive offloading. It supports students in storing information and structuring their own knowledge and ideas before making them explicit. The *Status bar* displays which group members are logged into the system and which tool a group member is currently using. It is meant to support students in raising group members' awareness.

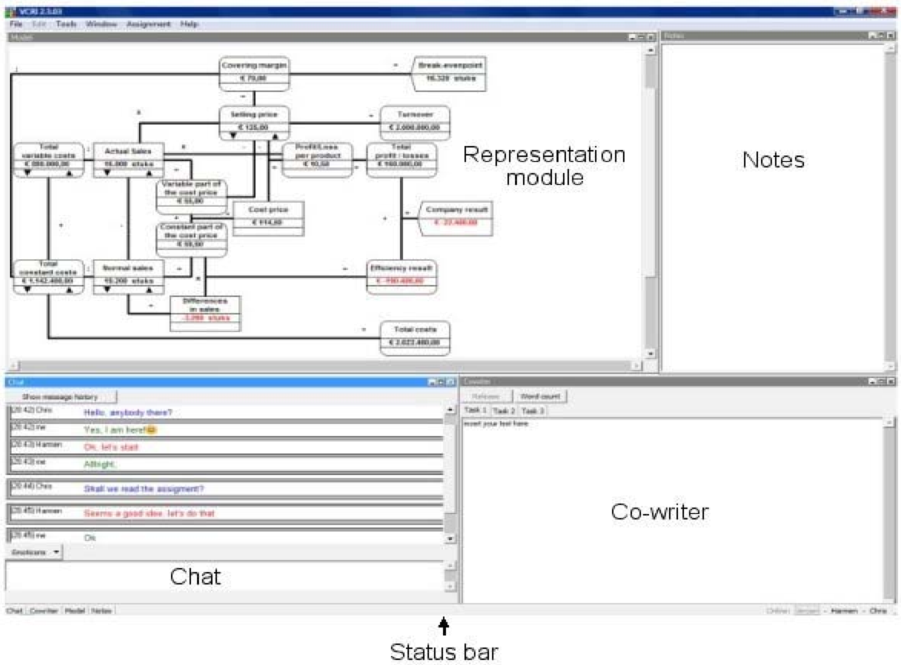

Figure 1. Screenshot of the VCRI-program.

Learning task and design of the tool

All groups worked on a complex business-economics problem in which they had to advise an entrepreneur about changing the business strategy in order to make the business more profitable (i.e., achieve a better company result). To provide a suitable advice, students had to perform three different part-tasks, namely (1) determine the main concepts responsible for the company's results and relate them to the problem, (2) determine how certain interventions (i.e., changes of the business strategy) affect company results, and (3) compare these consequences and formulate a final advice based on this comparison. The *scripting module* divided the learning task into three phases (i.e., problem orientation, problem solutions, solution evaluation) each focused on one of the part-tasks. All groups were 'forced' to perform the part-tasks in a predefined order; they could only start with a new part-task after finishing the earlier phase. When group members agreed that a part-task was finished, they had to 'close' that phase in the *assignment menu*. This 'opened' a new phase, which had three consequences for the groups, namely they (1) received a new part-task (2) had to enter their new answers in a different window of the *Co-writer* and could not alter, but could still see, their prior answers, and (3) received a different ER (only in the fourth, matched, experimental condition). A description of the different phases for the fourth experimental conditions follows. All other experimental conditions received the part-tasks in the same order (i.e., scripting module), but did not receive different ERs in the *representation module*.

The *problem orientation phase* focused on creating a global problem representation by asking students to explain what they thought the problem was, and describing what the most important concepts were for coming to an advice. During this phase, students received the conceptual ER (see Figure 2), which made two aspects salient, namely the core concepts and which concepts were related to each other. Students could, for example, see that the 'company result' is determined by the 'total profit' and the 'efficiency result'. This should make it easier to create an overview of all relevant concepts (i.e., broadening the problem space), which supports students in finding multiple solutions to the problem in the following phase. The simplicity of the conceptual ER supports the creation of a global problem representation which can be elaborated on in subsequent problem phases that contain part-tasks that require the support of more expressive ERs, that is: casual and quantitative problem representations.

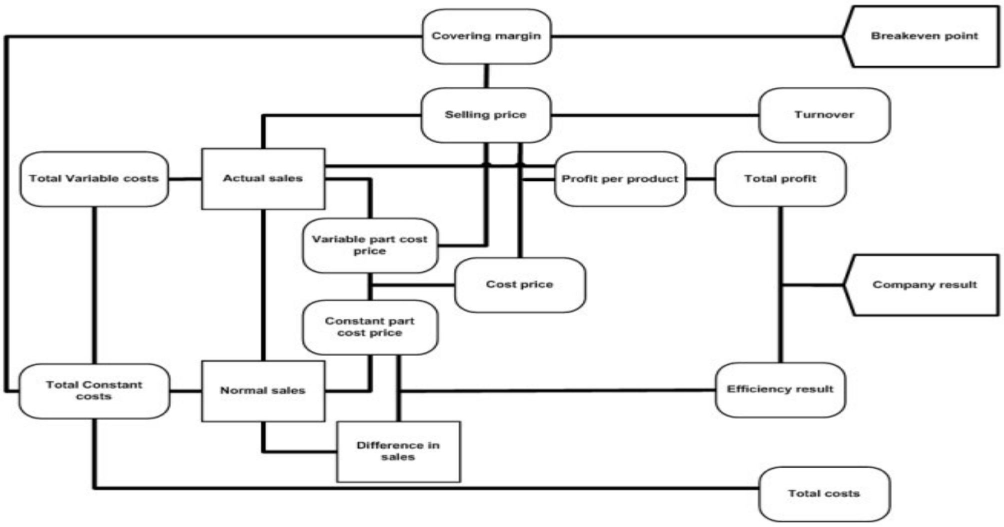

Figure 2. Conceptual ER.

The *problem solutions phase* aimed at creating a scientific problem representation (i.e., explicating the underlying business-economics principles) by asking students to formulate several solutions to the problem. During this phase, students received the causal ER (see Figure 3), in which the causal relationships - visible through the arrows showing direction of the relationship between the concepts - were specified. The causal ER also contributed to increasing conceptual understanding by providing students with nine possible interventions (i.e., changes of the business strategy), each of which had a different effect on the company results. This should make it easier to explore the solution space and therefore should support students in finding multiple solutions to the problem. Students could, for example, see that receiving a rebate from a supplier affects the 'variable part cost price', which in turn affects the 'cost price'. The conceptual ER is too simplistic for performing this part-task because the relations in that ER were not specified and the students did not receive any information about possible solutions. This means that they had to produce the advice themselves, without having sufficient conceptual understanding of the knowledge domain. The simulation ER used in the following phase has a quantitative character which supports testing the proposed advices, but is difficult to grasp without a properly developed qualitative understanding.

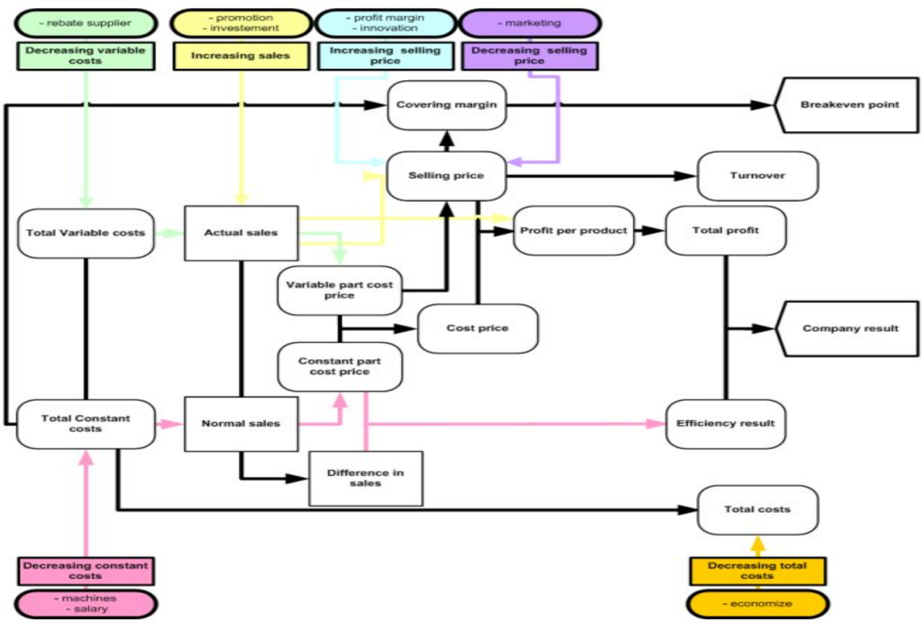

Figure 3. Causal ER.

The *solution evaluation phase* aimed at increasing conceptual understanding with the aid of a quantitative problem representation. Students were asked to determine the financial consequences of their proposed solutions, and to formulate a final advice for the entrepreneur by negotiating the suitability of the solutions with each other. During this phase, students received a simulation ER which enabled them to manipulate some of the concepts by clicking on the arrows in the boxes. The results obtained through the simulations should facilitate determining and negotiating the suitability of their proposed solutions and coming to a final advice. Students could, for example, test how a supplier rebate (i.e., decrease of the total variable costs) affects the 'cost price' and how this in turn affects the 'company result'. Only the simulation ER is capable of providing this kind of support, because the relationships between the concepts in this ER were specified as equations (i.e., weight of the relationship).

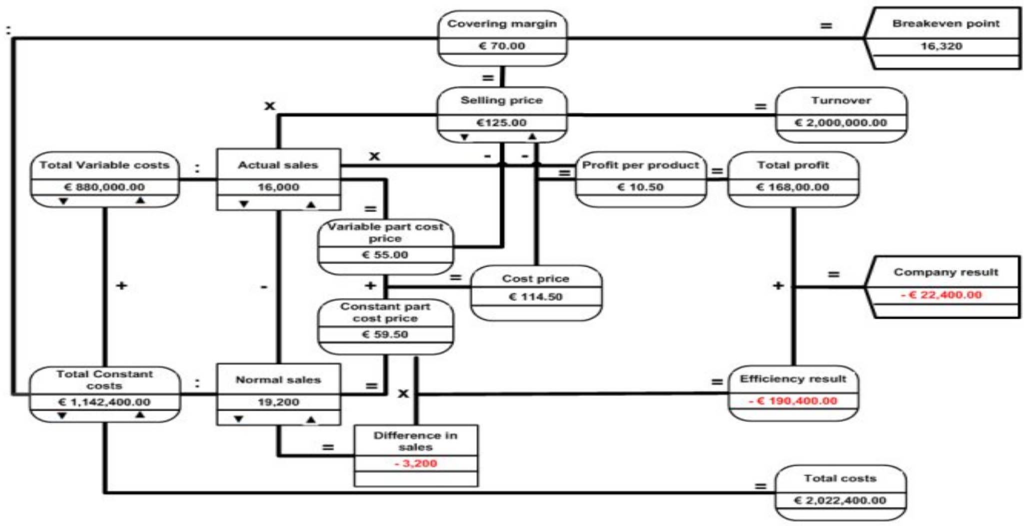

Figure 4. Simulation ER

Procedure

In total, students devoted three, 70-minute lessons to the whole learning task during which each student worked on a separate computer in a computer room. Before the first lesson, students received information about the learning task and group composition. Furthermore, a pre-test (45 minutes) was administered to determine prior domain knowledge and relevant personal information (e.g., age, sex). Thereafter, students worked on the learning task in the computer room, whereby all actions and answers to the part-tasks were logged by the VCRI-program. During these lessons, the teacher was on stand-by for task-related questions and a researcher was present for technical support. After the final computer lesson, a post-test (45 minutes) was administered for determining the amount of domain knowledge of the students after the intervention.

Measures

Learning gains

Domain knowledge was measured with a pre-test (20 items, $\alpha = .60$) and a post-test (20 items, $\alpha = .65$). Based on work of Gagné, Wagner and Briggs (1992) a learning task analysis was conducted which resulted in 12 business-economics concepts. The concepts and their relationships can be understood conceptually (i.e., qualitative understanding of a concept), causally (i.e., qualitative understanding of the causal relationship between concepts), and mathematically (i.e., quantitative understanding of the relationships between concepts).

Task performance

The quality of the collaborative product was used as an indicator of task performance. To measure the effect of condition on group performance, an assessment form for each unit of the learning task was developed. All 41 items were coded as; 0, 1 or 2, whereby a '2' was coded when the answer given was of high quality (e.g., was more suitable). In total, groups could maximally score 82 points on the quality of the collaborative product. Table 2 shows the description and the reliability (Cronbach's alpha) for each unit of analysis.

Exclusion of groups from further analysis

From the 16 groups participating in the study, three (1 dyad and 2 triads) were excluded from the analyses because the group members did not participate in all lessons and scored unexplainably lower on the post-test. Task performance score of these groups was also unexplainably lower than for the other groups. We assume that this was not caused by the design of the experiment because the excluded groups came from different conditions.

Table 2: Items and reliability for the collaborative product (N = 13).

Unit	Description	Items	α
1. Suitability	Whether the group's answers were suited to the different part-tasks.	9	.81
2. Elaboration	Number of different business-economics concepts or financial consequences incorporated in the answers to the different part-tasks.	9	.56
3. Justification	Whether the groups justified their answers to the different part-tasks.	9	.71
4. Correctness	Whether the groups used the business-economics concepts and their interrelationships correctly in their answers to the different part-tasks.	9	.68
5. Continuity	Whether the groups made proper use of the answers from a prior problem phase.	2	.67
6. Quality advice	Whether the groups gave a proper final advice. - Number of business-economics concepts incorporated in the advice. - Number of financial consequences incorporated in the advice. - Whether the final answer conformed to the guidelines provided.	3	.76
7. Total	Overall score on the collaborative product.	41	.92

Results

Learning gains

The overall mean score on the pre-test was 12.19 (*SD* = 2.12; max = 20). The overall mean on the post-test score was 12.58 (*SD* = 2.71; max = 20). The *t*-test showed that the overall post-test score of 31 students (not all 39 students were present when the pre- and / or post-test were administered) was not significantly higher than the overall pre-test score ($t(31) = 12.58$, $p > .05$). There was, thus, no increase in learning. One way ANOVA showed no significant difference between the conditions on the pre-test score ($F(3, 27) = 2.09$, $p > .05$). This means that students did not differ in the amount of prior knowledge and there was, therefore, no need to correct for this variable. Table 3 shows the overall and condition means and standard deviations on the pre-test and post-test scores.

Of the total variance on post-test score 59% could be explained by the variance on group level. This means that working in groups accounts for more variance on individual post-test scores than individual characteristics of the group members (e.g., age, sex). For this reason, multilevel analysis was used for determining the effect of condition on post-test score (Kenny, Kashy, & Cook, 2006). Analysis showed that students in the conceptual condition scored significantly lower than those in the other conditions ($\beta = -2.94$, $p = .01$; two-sided), and (2) there was a trend that students in the causal condition scored significantly higher than the students in the other conditions ($\beta = 1.52$, $p = .07$; two-sided). The model fit the data ($\chi^2(3) = 14.34$, $p = .00$) and could, therefore, be used to account for the differences in variance on the post-test score.

These results are not completely in line with our first hypothesis. Students in the match condition only scored higher on the post-test in comparison to students in the conceptual condition. Furthermore, on average, students in the causal condition had the highest score on the post-test.

Table 3: Means and standard deviations of pre-test and post-test scores for conditions (N = 31).

Unit	Condition									
	Conceptual (n = 12)		Causal (n = 6)		Simulation (n = 6)		Match (n = 7)		Overall (n = 31)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pre-test	13.11	1.45	12.44	2.65	10.50	2.07	12.14	1.57	12.19	2.12
Post-test	10.00	2.59	14.55	1.74	13.20	2.05	13.00	1.67	12.58	2.71

Task performance

One way MANOVA on the total score on the collaborative product showed a significant difference for condition ($F(3, 9) = 1.99$, p = .04; one-sided; Pillai's Trace = 2.00; partial *eta* squared = .67). Bonferroni post hoc analyses showed that groups in the match condition scored significantly higher than groups in both the conceptual ($p = .02$; one-sided; $d = 2.28$) and the simulation condition ($p = .05$; one sided; $d = 1.90$). Differences between other conditions were not significant. Table 4 shows the overall and condition means and standard deviations of the scores on the collaborative product.

When the results for the dependent variables were considered separately, condition effects were found for suitability ($F(3, 9) = 4.49$, $p = .02$; one-sided), elaboration ($F(3, 9) = 3.13$, $p = .04$; one-sided) and correctness ($F(3, 9) = 4.25$, $p = .02$; one-sided). The mean scores indicated that there were several significant differences between conditions. First, groups in the match condition scored significantly higher on suitability than groups in both the conceptual ($p = .03$; one sided; $d = 3.61$) and the simulation condition ($p = .05$; one sided; $d = 3.28$). Second, groups in the match condition scored significantly higher on elaboration than groups in the conceptual condition ($p = .04$; one sided; $d = 1.57$). Third, groups in the match condition scored significantly higher on correctness than groups in the conceptual condition ($p = .03$; one sided; $d = 2.13$) and a trend was found in comparison to the groups in the simulation condition ($p = .07$; one sided; $d = 1.85$).

These result confirmed our second hypothesis, namely that groups that received a matching ER for each part-task scored higher on task performance (i.e., the collaborative product).

Table 4: Means and standard deviations of the collaborative product scores for conditions ($N = 13$).

Unit	Condition									
	Conceptual ($n = 4$)		Causal ($n = 3$)		Simulation ($n = 3$)		Match ($n = 3$)		Overall ($N = 13$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Suitability (max 18)	10.75	1.50	13.67	1.52	11.33	4.16	17.00	1.73	13.00	3.29
Elaboration (max 18)	3.75	2.06	6.67	2.08	6.00	2.00	9.67	3.78	6.31	3.15
Justification (max 18)	3.25	2.06	4.67	3.06	3.00	3.00	8.00	4.00	4.62	3.31
Correctness (max 18)	4.50	1.29	6.33	3.77	5.33	0.58	10.67	2.89	6.54	3.21
Continuity (max 4)	2.00	1.41	2.00	1.00	2.00	1.73	3.67	0.58	2.38	1.33
Final answer (max 6)	2.50	0.58	3.67	0.58	3.33	2.52	3.33	1.53	3.15	1.35
Total score (max 82)	26.75	4.17	37.00	7.00	31.00	12.00	52.33	11.24	36.00	12.67

Conclusion and Discussion

This study shows that structuring a complex problem-solving task into ontologically distinct part-tasks (i.e., phases) and providing the part-tasks with congruent representations leads to better problem solutions (i.e., task performance). The match condition outperformed both the conceptual and the simulation condition, the answers were more suited for a specific part-task, contained more business-economics concepts and financial consequences, and were more often correct. These results mostly confirmed our expectation and are in line with those of Ploetzner et al. (1999), who also stress the importance of sequencing and interrelating qualitative and quantitative aspects of the knowledge domain during collaborative problem solving. No differences were found between the match and the causal condition. Apparently the causal representation provided more support than both the conceptual and the simulation representation did, but in combination these three representations resulted in a higher score on task performance. Furthermore, it was expected that gradually shifting from a conceptual to a simulation representation would also result in higher individual scores on the post-test (i.e., learning gains). Students in the conceptual condition were indeed outperformed by the students in the other conditions. However, in contrast to our expectation, students in the causal condition also scored better on the post-test than students in both the simulation and the match condition.

It appears that providing only a conceptual or a mathematical perspective does not support students in applying and acquiring domain knowledge. Students in both the causal and the match condition were supported, but remarkably no significant differences were found between these two conditions. Although the causal representation also provides one perspective, students in this condition outperformed students in the match condition on individual learning gains, but were outperformed by the match condition on group task performance. In our opinion, there seem to be four explanations that might account for this result. First, there could be an underestimation of the importance of causal reasoning (Jonassen, & Ionas, 2008). The causal representation provides all relevant concepts and their causal interrelationships. It provides multiple qualitative perspectives on the domain which are also comprehensible for the students. Combining the causal representation with both the conceptual and the simulation representation could be detrimental for individual learning because of the difficulty in integrating the different perspectives on the domain (Ainsworth, Bibby, & Wood, 2002). Second, the design of the tool was primarily aimed at supporting students in applying domain knowledge in order to come to better and richer solutions. According to Kirschner, Sweller, and Clark (2006), solving complex problems is an instructional method based on the epistemological content (i.e., methods and processes) instead of the pedagogical content (i.e., acquiring knowledge) of a knowledge domain. Such a learning experience, therefore, mainly focuses on the application of knowledge (i.e., task performance) and due to the required cognitive activity may hinder students in acquiring a well developed understanding of the knowledge domain (i.e., learning). In this respect, students in the causal condition were less supported in task completion which might have supported them in acquiring more domain knowledge. Third, the post-test only measured the acquired conceptual understanding of the knowledge domain. It did, therefore, not enable students in the match condition to fully demonstrate their gained understanding of the knowledge domain. The difference between the design of the post-test and the nature of the collaborative task performance was perhaps less apparent for students in the causal condition. This could have made the post-test more suited for them in comparison to students in the match condition. Fourth, collaboration requires interaction in both the content space and the relational space from all group members. If the whole group is not able to cope with these activities, the collaboration process could have detrimental effects on group performance (Barron, 2003). We are currently analyzing the log files (i.e., dialogue-protocols) to determine what students talked about (i.e., content space) and how students managed their collaboration (i.e., relational space). These analyses should provide insight into the collaboration process and how it was affected by the design of the tool.

The results of this study have several limitations. First, the effects of the tool on group performance were based on only 13 groups. Second, this study was conducted in the field of business-economics. Although there are many other domains (e.g., science, physics, planning) in which qualitative and quantitative problem representations are required, the effect of a tool depends on the characteristics of the problem and the involved knowledge domain(s). Third, condition effects were found for task performance and learning gains, but when one inspects the standard deviations it appears that there are also differences between groups within the conditions. The present results of this study are solely focused on the question whether a difference in characteristics of a tool affects task performance and individual learning. Further analyses will be focused on why these differences occurred.

In sum, structuring the online collaborative performance of complex learning tasks into ontologically distinct part-tasks and providing congruent representations for each part-task (i.e., representational scripting) seems to broaden the perspective on designing CSCL-environments. It provides opportunities for combining the advantages of multiple tools in order to offer more suited support for the online collaborative performance of complex learning tasks. The design of the tool resulted in higher scores on group task performance in comparison to both the conceptual and simulation condition and also in more individual learning gains in comparison to the conceptual condition. At this stage, the reasons for the lack of significant differences between the causal and the match condition remain unclear. Keeping this lack and the limitations into mind, additional research into the effects of tools should be carried out to investigate the results and the collaboration process for multiple problems and in a diversity of knowledge domains.

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Is Representational Guidance Culturally Relative?

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Abstract: The basic hypothesis of this research project is that since the perception and appropriation of affordances vary across cultural dimensions, representational guidance may be culturally relative. An experimental study was conducted to evaluate this hypothesis. The study design consisted of three independent groups of dyads from similar or different cultures (American-American, American-Chinese, and Chinese-Chinese) doing collaborative problem-solving in a knowledge-mapping learning environment. Participants interacted through an asynchronous computer interface providing multiple tools for interaction (diagrammatic workspace, embedded notes, threaded discussion). Based on empirical findings documenting cross-cultural variations in communication and cognition, several research hypotheses were advanced. Statistical results show that members of different cultures appropriated the resources of the interface differently in their interaction, and formed differential relations with and impressions of each other. However, analyses of the individually written essays show no statistically significant differences in learning outcomes. Implications for CSCL are discussed.

Introduction

The central premise of the representational guidance line of work is articulated by Suthers (2001b) as:

> The major hypothesis of this work is that variation in features of representational tools used by learners working in small groups can have a significant effect on the learners' knowledge-building discourse and on learning outcomes. The claim is not merely that learners will talk about features of the software tool being used. Rather, with proper design of representational tools, this effect will be observable in terms of learners' talk about and use of subject matter concepts and skills.

The above hypothesis follows from two lines of reasoning. The first line of reasoning focuses on properties of representational notations (as realized in representational tools and artifacts) that can bias users of the notations to take certain actions over others (Suthers, 2001b). A given notation *constrains* what can logically be expressed, and information that is expressed will be differentially available depending on what the notation makes *salient* relative to a given user. These notational dimensions are not intrinsically social. The second line of reasoning identifies how the constraints and salience of notations amplify certain social interactions. As listed by Suthers and Hundhausen (2003), (1) the potential acts available in a notational system lead to *potential negotiations* between participants concerning how to act; (2) salient elements of a representation provide *referential resources* supporting further interaction about the ideas associated with those elements; and (3) mutual awareness of participants' orientation towards representations supports *implicit awareness* of each others' activity. Suthers and colleagues have experimentally demonstrated representational guidance effects in a variety of external representational learning environments, and under face-to-face and synchronous and quasi-asynchronous computer-mediated interactional conditions with dyads (Suthers & Hundhausen, 2003; Suthers, Hundhausen, & Girardeau, 2003; Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2008).

There are reasons to believe that representational guidance is relative to the cultural properties of the user. Four distinct lines of empirical research have demonstrated that:

1. *Culture influences social behavior* (House, Hanges, Javidan, Dorfman, & Gupta, 2004).
2. *Culture influences communication* (Hall, 1977).
3. *Culture influences cognitive processes* (Dimaggio, 1997; Nisbett & Norenzayan, 2002; Ross, 2004).
4. *Culture influences interacting with computers* (summarized in Vatrapu & Suthers, 2007).

The research project reported here builds upon the body of empirical work listed above and investigates the cultural relativity of representational guidance. The collaborative learning paradigm is grounded in social constructivist epistemology, with some researchers in Computer Supported Collaborative Learning (CSCL) adhering to a radically dialogical epistemology of intersubjective learning (see Suthers, 2006, for a discussion of different epistemologies in CSCL). CSCL emphasizes social interaction and in the era of globalization, social interaction could often be intercultural. Research into social aspects of Human Computer Interaction (HCI) has shown that even computer-literate users tend to use social rules and display social behavior in their interactions with computers (Reeves & Nass, 1996). Social behavior is strongly grounded in culture as every person carries within himself/herself patterns of thinking, feeling and potential acting. To learn new patterns of thinking, feeling and acting one has to unlearn and/or adapt old patterns, a more difficult task than acquiring them in the first place (Vatrapu & Suthers, 2007). This research's particular concern is to empirically investigate the extent to which culture influences how participants in intra- and inter- cultural computer supported collaborative learning environments (a) appropriate affordances, (b) perceive themselves and their collaborative others, and (b) subsequently perform on individual learning outcomes assessments. This research is not merely about Human Computer Interaction (HCI)—i.e., interacting with technology—it is also about technological intersubjectivity (TI)—i.e., interacting with people. In this paper, we focus on the appropriation of affordances and individual learning outcome measures. For results related to TI, please refer to (Vatrapu, 2007, 2008; Vatrapu & Suthers, 2009).

Methods

We designed an experimental study that introduced a variation in the cultural background of individuals (by selecting participants from a nation-state based ethnically stratified random sampling frame) but kept invariant the technological interface, collaboration task, and interactional setting. The experimental study investigated how pairs of participants from similar or different cultures (American-American, American-Chinese, and Chinese-Chinese) appropriated affordances in a quasi-asynchronous computer supported collaborative environment with external representations in order to collaboratively solve a public health problem.

Experimental Design

The experimental study design consisted of three independent groups of dyads from similar and different cultures (American, Chinese) doing collaborative problem solving in a knowledge mapping learning environment (described below). The three experimental conditions were the Chinese-Chinese *intra*-cultural condition, the American-American, *intra*-cultural condition and the Chinese-American *inter*-cultural condition.

In all three experimental conditions the dyads were given the same experimental task (described below). All the dyads interacted in the same software environment after reading the same instructions, software tutorial and demonstration. Construct validity was addressed by using existing instruments with high validity and reliability (Bhawuk & Brislin, 1992; Harper, Slaughter, & Norman, 2006; House et al., 2004; Schwartz et al., 2001; Suinn, Ahuna, & Khoo, 1992).

Materials

Software

The software environment used in this study was originally constructed in support of a research program on how representational affordances influence and are appropriated by collaborating dyads (Suthers et al., 2008). We chose to use a configuration of this environment that offered a diversity of resources for interaction, so that there would be sufficient degrees of freedom to allow cultural influences to be manifest. Figure 1 displays a captioned screenshot of the environment used in the experimental study. It has an *information viewer* in which materials relevant to the problem are displayed. This information viewer functions as a simple web browser, but the presentation of materials is constrained as discussed in the next section. The environment has a shared workspace or *information organizer* in which participants can share, organize, and discuss information they gather from the problem materials as well as their own interpretations and other ideas. The *discussion tool* below the information viewer enables participants to discuss their ideas in a threaded discussion format.

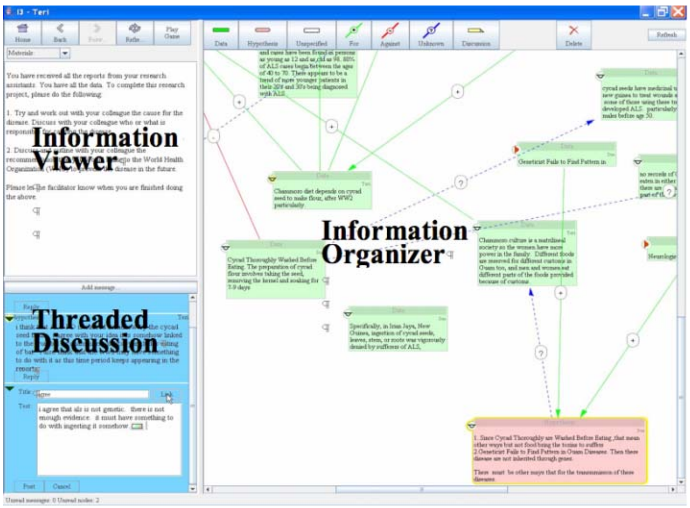

Figure 1: Screenshot from an experimental session

The information organizer includes tools derived from Belvedere (Toth, Suthers, & Lesgold, 2002) for constructing knowledge objects under a simple typology relevant to the experimental task of identifying the cause of a phenomenon (e.g., a disease), including data (green rectangles, for empirical information) and hypotheses (pink rectangles, for postulated causes or other ideas). There are also *linking* tools for constructing consistency ("for") and inconsistency ("against") relations between other objects, visualized as green links labeled "+" and red links labeled "-" respectively. "Unspecified" objects and "unknown" links provide for flexibility. Finally, an *embedded note* object supports a simple linear (unthreaded) discussion that appears similar to a chat tool; except that a note is interactionally asynchronous and one can embed multiple notes in the knowledge map and link them like any other object. In the threaded discussion section of the environment (see

Figure 1) participants can embed references to knowledge map objects in the threaded discussion messages by selecting the relevant graph object(s) while composing the message. The references show up as small icons in the message. When the reader selects the icon, the corresponding object in the knowledge map is highlighted, indicating the intended referent.

Awareness of Artifacts and Activity

The software supports mutual awareness of participants' *artifacts*. All knowledge map nodes and threaded discussion messages show the name of the creator. The mutual awareness features of *artifacts* and of *activity* are as follows: "ego" refers to the participant using the screen at hand and "interlocutor" to the study partner. The screen name selected by each participant appears on the title bar of ego's application window and on knowledge map nodes and message created by ego. Artifacts created by the interlocutor are marked with a solid red triangle in the top right corner until they are opened by ego. Artifacts created by ego are marked with a yellow circle until they are read by the interlocutor. Further, the number of unread nodes and unread messages are displayed at the bottom of the window. Thus, each ego participant is provided with cues identifying new artifacts from the study partner as well as which artifacts are not yet read by their partner.

Protocol for Workspace Updates

To simulate asynchronous online interactions, the actions of each participant in the shared workspace were not displayed immediately in the other participant's workspace. As a person worked, the actions of that person were sent to the other participant's client application, but were queued rather than displayed. Participants were given a new report (discussion forthcoming) after playing the game of Tetris™. Tetris™ was chosen as it presents a different sensory-motor perceptual task than the primary experimental task of reasoning about conflicting evidence (described below), and simulates taking a break from study (Suthers et al., 2008). After the game of Tetris™, all of the currently queued actions on that client were displayed. The delayed updating protocol simulates one aspect of the experience of asynchronous computer supported collaboration: a participant sees what one's partner has done upon returning to a workspace after a period of time. It excludes the possibility of synchronous conversation in which one participant posts a message in the workspace and receives an immediate reply.

Alternates for Action

The software environment provides multiple alternatives for action. Participants have multiple ways of sharing the information presented to them (threaded discussion, embedded notes, and knowledge-map). Participants can discuss the task at hand or any other topic of interest using the threaded discussion tool to the bottom-left of the knowledge map or the embedded notes tool within the knowledge-map. Participants can also use the knowledge-map objects to interact. Participants can refer to artifacts by deictic referencing (this, that, etc…) or use the cross-referencing feature of the threaded discussion. Participants can externalize the perceived relations between their concepts by creating evidential relation links between objects in the knowledge-map, by spatial arrangement such as proximity and clustering, or by mentioning these relations in discussion. The research strategy was to provide participants with a feature rich collaborative environment with multiple alternates for action. By incorporating systematic variation in the assignment of participants to the collaborative dyad based on their cultural background and gender, the experimental design strategy was to observe and evaluate systemic differences in how participants used the tools and resources of the technology (appropriation of affordances).

Topics

The study required participants to identify the cause of a disease on the island of Guam. This disease has been under investigation for over 60 years, in part because it shares symptoms with Alzheimer's and Parkinson's diseases. Only recently have investigators converged on both a plausible disease agent (a neurotoxic amino acid in the seed of the Cycad tree) and the vector for introduction of that agent into people (native Guamians' consumption of fruit bats that eat the seed). Over the years numerous hypotheses have been proposed and a diversity of evidence of varying types and quality explored. The unlikelihood of prior exposure to the problem, multiple plausible hypotheses, contradicting information, ambiguous data and high interpretation make this a good experimental study task for eliciting cultural differences in approaches to complex problems. All experimental study materials were in English. All participants began with a mission statement that provided the problem description and task information. Four mission statements corresponding to the four participant assignment configurations (Chinese vs. American x P1 vs. P2) were administered accordingly. Evidence was distributed across participants in a "hidden profile" (Stasser & Stewart, 1992) design that required participants to share evidence in order to expose the weakness of some proposed causes (e.g., genetics, minerals in the drinking water) as well as to construct the more complex explanation involving bats and cycad seeds (see Vatrapu, 2007, 2008). Identification of this hypothesis involves making connections across reports given to the two participants over time and considering and rejecting other explanations. The study task and task materials are designed to highlight social division of cognitive labor. The experimental study encouraged participants to interact with each other by including the following reinforcing task instruction on each report (set of 4 articles): "*Please share and discuss this information with you colleague. Please play the game to receive the next report from your research assistant.*"

Research Hypotheses

This section discusses several research hypotheses generated from culture theory and empirical findings in cross-cultural psychology.

<u>Research Hypothesis 1 (RH1):</u> Chinese participants will appropriate affordances to reference regions of the knowledge maps and groups of knowledge map objects; American participants on the other hand will appropriate affordances to refer to individual objects. Experimental studies of the manipulation of "focal" objects in perceptual fields have found that East-Asian participants attended more to the perceptual field as a whole (Nisbett & Norenzayan, 2002). American participants attended more to the "focal" objects. In a knowledge map environment, Chinese participants might pay attention to a group of interrelated knowledge map objects whereas American learners might pay more attention to individual objects and evidential relational links. The cultural difference in attention might vary the ways in which referencing and deixis are carried out in collaborative discourse.

<u>Research Hypothesis 2 (RH2):</u> Chinese participants will create a greater number of evidential relation links in the knowledge map compared to American participants. East-Asian participants in experimental studies perceive relationships between objects more than American participants in the same experiments (Nisbett & Norenzayan, 2002). We predicted that compared to the Americans, Chinese participants will perceive more relationships between the information in knowledge map and instructional materials leading to the creation of a greater number of evidential relation links in the knowledge map.

<u>Research Hypothesis 3 (RH3):</u> American participants will create more threaded discussion messages compared to Chinese participants. This hypothesis was derived from the cultural difference of low-context vs. high-context communication (Hall, 1977) between American participants and Chinese participants and the cultural differences in attention and perception (Nisbett & Norenzayan, 2002). According to Edward Hall (1977), high-context cultures (e.g., Chinese) privilege social motivation in communication and low-context cultures (e.g., American) prefer rational attributes in communication. In collaborative problem solving environments, the communicative context style of the participants can influence how they engage in active discussion, elaboration and reflection. The low-context communication style of American participants might be more conducive to threaded discussion than embedded discussion.

<u>Research Hypothesis 4 (RH4):</u> Chinese participants will create more embedded discussion notes compared to American participants. This hypothesis was also made from the cultural difference of low-context vs. high-context communication (Hall, 1977) discussed above. Chinese participants might perceive and appropriate affordances for embedded discussion as it is in the same informational, communicational, and interactional space as the collaborative knowledge-map.

<u>Research Hypothesis 5 (RH5):</u> More American participants will explicitly discuss information sharing strategies and techniques than Chinese participants. Interactions in socio-technical environments are a dynamic interplay between ecological information as embodied in artifacts and individual actions grounded in cultural schemas. In low-context cultures, members might be more inclined to influence others to act by explicitly pointing out pertinent information sharing, reporting, and archiving strategies and techniques.

<u>Research Hypothesis 6 (RH6).</u> More American participants will explicitly discuss knowledge map organization strategies and techniques than Chinese participants. This prediction was made based on both the communication style differences (Hall, 1977) and knowledge organization differences between a reliance on categories of objects and events vs. relationships between objects (Nisbett & Norenzayan, 2002).

Participants

Participant recruitment drew from the graduate student population at the University of Hawai'i. Participant stipends were US$75.

There is a tendency in cross-cultural computer mediated communication research to use cultural models bounded by modern nation-states. Nation-state boundaries are not tantamount to culture, but nationality-based sampling frames are a methodologically convenient way to categorize participants provided that cultural differences are assessed on validated instruments. To address the possible mismatch of nation-state boundaries and cultural identity, previously validated instruments were used for assessing cultural differences (as a "manipulation check"). The Portrait Values Questionnaire (PVQ) (Schwartz et al., 2001) was used to assess cultural values at the individual level. The GLOBE instrument (House et al., 2004) was used to assess cultural dimensions at the group level. Participants were randomly assigned to either the intra- or the inter- cultural profiles and the same or different gender profiles. Excluding 6 pilot studies, a total of 33 experimental sessions involving 66 pairs of participants were conducted. Data from 3 experimental sessions was discarded due to issues of a missing screen recording, a software crash and a disqualification. There were 10 pairs of participants for each of the three treatment groups: Chinese-Chinese intracultural; American-American intracultural, and American-Chinese intercultural groups. All the three conditions were gender-balanced as prior research has shown that gender can substantially influence social interaction (Tannen, 1996). Each treatment group included 3 female-female, 3 male-male and 4 female-male dyads.

Instruments

The different instruments used for the measurement of the constructs are listed below.

Demographic Questionnaire

A demographic questionnaire (see Vatrapu, 2007, pp. 275-276) collected participants' prior knowledge about the study problem, familiarity with each other, with online learning environments, with usability evaluation studies as well as data about age, gender, ethnic background, duration of stay in the USA, and duration of stay in the state of Hawai'i. All participants were requested to make a self-report of their cumulative grade point average (CGPA). Participants signed a release form for obtaining official records of their CGPA and graduate record examination (GRE). Chinese participants authorized release of their test of English as a foreign language (TOEFL) scores (see Vatrapu, 2007, p. 277).

Self-Perception: Portrait Value Questionnaire (PVQ)

The 40-item version of the PVQ instrument (see Vatrapu, 2007, pp. 277-279) recommended for intercultural contexts (Schwartz, S. H, personal communication) was administered. The PVQ scale measured cultural values at the individual level. Cronbach's "alpha measures of internal consistency range from .37 to .79 for the PVQ (median, .55)" (Schwartz et al., 2001, p. 532). Gender specific versions of the self perception PVQ scale were administered.

GLOBE Cultural Dimensions Instrument

The GLOBE instrument (House et al., 2004) was used to measure cultural values at the group level (see Vatrapu, 2007, pp. 280-293). Section 1 and Section 3 of the original GLOBE instrument were administered. Section 1 of the GLOBE instrument measures a responder's perceptions of their society ("Section 1 — The way things are in your society"). Section 3 of the GLOBE instrument measures a responder's preferences for their society ("Section 3 — The way things generally should be in your society"). According to the "Guidelines for the Use of GLOBE Culture and Leadership Scales", "the construct validity of the culture scales was confirmed by examining the correlations between the GLOBE scales with independent sources (e.g., Hofstede's culture dimensions, Schwartz's value scales, World Values Survey, and unobtrusive measures)" (House et al., 2004).

Individual Essays

Participants were required to write individual essays following the collaborative science problem solving exercise. Essay writing instructions were identical for all participants. The instructions asked the participants to state the hypotheses they considered. They were also asked whether and how their hypotheses and conclusions differed from those of their study partners.

Peer-Perception: Portrait Value Questionnaire (PVQ]

The second immediate post-test was the administration of the Portrait Value Questionnaire (PVQ) (Schwartz et al., 2001) instrument with a reversal of the direction of assessment (see Vatrapu, 2007, pp. 304-306). This time instead of assessing themselves, participants assessed their partners.

Acculturation: SL-ASIA Questionnaire

The experimental study recruited Chinese graduate students at a university in the USA. Acculturation occurs when members of one culture live in another culture. Acculturation becomes another variable in cross-cultural research. This can be controlled by measuring the acculturation level of the participants belonging to the minority immigrant culture (Triandis, Kashima, Shimada, & Villareal, 1986). This research project used the Suinn-Lew Asian Self Identity Acculturation (SL- ASIA) scale (Suinn et al., 1992) to measure the acculturation levels of the Chinese participants (see Vatrapu, 2007, pp. 307-311). Suinn et al. (1992) reported an internal-consistency estimate of .91 for the SL-ASIA instrument.

Intercultural Sensitivity: Intercultural Sensitivity Instrument

Intercultural sensitivity is a vital skill for intercultural collaborations (Bhawuk & Brislin, 1992). The intercultural sensitivity instrument (ICSI) (Bhawuk & Brislin, 1992) was used to measure the American participants' self-assessment of intercultural sensitivity (see Vatrapu, 2007, pp. 312-315). Bhawuk and Brislin (1992) report that "the ICSI was validated in conjunction with intercultural experts at the East-West Center with an international sample (n=93)" (p. 423). "China" substituted for "Japan" in the original ICSI instrument for this experiment. Pilot testing showed that Part 3 of ICSI was irrelevant to the experimental task and hence not used.

User Satisfaction: QUIS Questionnaire

The QUIS 7.0 questionnaire (Harper et al., 2006) was administered to collect the participants subjective perceptions and preferences of the learning environment (see Vatrapu, 2007, pp. 316-321). The QUIS has high reliability (Cronbach's alpha = 0.95 and high construct validity (alpha = 0.86) (Harper et al., 2006). The QUIS instrument also measured participants' subjective satisfaction with the instructions and the software tutorial besides various subjective user satisfaction measures.

Procedure

Approval for use of human subjects was sought and granted, and informed consent was obtained from all participants for both the pilot studies and the experimental studies. Two students participated in each session. Experimental sessions lasted about 3.5 hours on average. After signing the informed consent forms, participants completed a demographic questionnaire. They were then given a CGPA/GRE/TOEFL score release form, the Self-Perception PVQ (Schwartz et al., 2001) and the GLOBE instrument (House et al., 2004). Participants were next trained to use the software. After the software demonstration, the two participants were led back to their respective workstations in two different rooms to begin work on the study task. Participants had up to 90 minutes to work on the information available for this problem. The update protocol described in (Suthers et al., 2008) was used to synchronize the workspaces of the two participants. At the conclusion of the investigative session, each participant had up to 30 minutes to write an individual essay. The essay focused on the hypotheses that were considered, the evidence for and against these hypotheses, and the conclusion reached. The software environment remained available to each participant during the essay writing, but the participants were requested not to engage in any further communication. After each participant had finished writing the individual essay, the other-perception PVQ instrument (Schwartz et al., 2001), and the QUIS instrument (Harper et al., 2006) were administered. The SL-ASIA instrument (Suinn et al., 1992) was administered to assess acculturation of Chinese participants. The ICSI instrument (Bhawuk & Brislin, 1992) was administered to assess inter-cultural sensitivity of American participants. This concluded the experiment.

Results

The data generated were then analyzed at four levels of *culture* (comparing American to Chinese participants), *gender* (comparing Female to Male), *dyadic culture* (comparing American-American, American-Chinese and Chines-Chinese dyads) and *dyadic gender* (comparing (Male-Male, Male-Female and Female-Female dyads). Unless otherwise stated, no significant differences were found for gender and dyadic gender levels.

Demographics

There was no significant difference in age at any of the four levels of analysis. As expected, American participants spent significantly more time in the USA than the Chinese participants. On the other hand, the time spent by the participants in Hawaii with respect to culture and gender was not statistically significant. This was done as control for context effects. There were no significant differences at any of the four levels of analysis for prior experience with experimental studies, prior knowledge about the experimental task, and partner familiarity. Further, results for the Learning section of the QUIS instrument showed no significant difference on the ease of learning the software usability measure at any of the four levels of analysis. Results for the Tutorial section of the QUIS instrument showed no significant difference for participants' subjective evaluation of the software demo and experimental instructions at any of the four levels of analysis. Therefore, experimenter bias and "demand characteristics" can be confidently ruled out as confounding factors.

Culture Measures

As mentioned earlier, Portrait Values Questionnaire (PVQ) (Schwartz et al., 2001) was used to measure culture at the individual level. The GLOBE instrument (House et al., 2004) was used to measure culture at the group level. Similarly, significant differences resulted on both sections of the GLOBE instrument as well as the PVQ instrument. Significant differences observed on the GLOBE instrument correlated with those observed on the PVQ instrument. None of the Chinese participants had high acculturation scores and none of the American participants scored lower on intercultural sensitivity. In summary, even though a nation state based stratified random sampling frame was employed; systemic variation between the two participant groups was documented and not stereotypically assumed.

Hypotheses Testing

For RH1, video analysis of the screen recordings of participant sessions was done to obtain counts of *referencing* objects or regions of the knowledge map. For RH2, RH3, and RH4 counts for *evidential relation* *links, threaded discussion messages* and *embedded discussion notes* were obtained from the software logs of participant sessions. For RH5 and RH6 participants' logs were coded for discussion of information sharing and knowledge-map organization strategies. An example of information sharing strategy is "*I think we should chunk related information (e.g., diet, culture, genetics) to make it easier to fit the 'pieces' together and connect them to hypotheses*." An example of a knowledge-map organization strategy is "*Lets use the top left to add new ideas / data that has not been connected to anything*." Table 1 presents a summary of the null hypothesis significance testing results: overall, significant differences were observed for 5 of the 6 theoretical predictions. Table 2 below presents a summary of the results between the three intra- and inter- cultural dyadic groups: overall, significant differences were observed on 4 of the 6 dependent measures.

Table 1: Summary of Hypotheses Testing Results for the Two Cultural Groups

	American Mean (SD)	**Chinese Mean (SD)**	**Test-Statistic (p-value)**
RH1	None: 19 Unit:2 Composite:9 Region:0	None: 21 Unit:3 Composite:3 Region:3	χ^2 (3,60)=6.30, p=0.09†
RH2	22.17(12.44)	15.87(7.50)	F(1,56)=5.542, p=0.022*
RH3	10.13(5.18)	6.37(4.59)	F(1,56)=8.878, p=0.004**
RH4	3.37(4.05)	5.13(6.08)	F(1,56)=1.727, p=0.19
RH5	No: 9 Yes:21	No:19 Yes:11	χ^2 (1,60)=6.70, p=0.0097**
RH6	No: 14 Yes:16	No:24 Yes:6	χ^2 (1,60)=7.18, p=0.0074**

† p<0.10, * p<0.05, ** p<0.01

Table 2: Summary of Hypotheses Testing Results for the Three Dyadic Cultural Groups

	American-American Mean (SD)	**American-Chinese Mean (SD)**	**Chinese-Chinese Mean (SD)**	**Test-Statistic (p-value)**
RH1	None:15, Region:0, Unit:1, Composite:4	None:10, Region:2, Unit:2, Composite:6	None:15, Region:1, Unit:2, Composite:2	χ^2 (6,60)=5.65, p=0.46
RH2	21.05(10.95)	20.95(12.13)	15.05(7.83)	F(2,57)=2.16, p=0.13
RH3	9.05(5.35)	10.85(5.06)	4.85(3.18)	F(2,57)=8.84, p<0.0001**, partial η^2=0.24
RH4	4.35(4.43)	1.95(3.73)	6.45(6.23)	F(2,57)=4.157, p=0.02*, partial η^2=0.13
RH5	No:4 Yes:16	No: 10 Yes:10	No: 14 Yes:6	χ^2 (2,60)=10.18, p=0.006**
RH6	No:8 Yes:12	No:13 Yes:7	No:17 Yes:3	χ^2 (2,60)=8.76, p=0.013*

* p<0.05, ** p<0.01

Individual Learning Outcomes: Analysis of Individually Written Essays

Each participant wrote an individual essay at the end of their dyadic collaboration. The software environment was available for the participants during the essay writing process. For the individual learning outcomes analysis of the essays, two coders analyzed the essays for (1) number of hypotheses mentioned by each participant, (2) participant's perception of study partner's divergence on hypotheses, (3) overall agreement between the two participants on final conclusion, and (4) Latent Semantic Analysis (LSA) of pair agreement of the individually written essays of the two participants. The two coders analyzed essays from six sessions (2 sessions were selected from each of the three experimental conditions: American-American, Chinese-American, and Chinese-Chinese). Intercoder reliability measures were estimated on these initial coding (6 coded sessions = 20% of 30 total sessions), discrepancies were corrected, and the second coder then coded the rest of the sessions.

Individual Essays: Number of Hypotheses Mentioned by Each Participant

The first item in the essay writing instructions asked participants to describe the hypotheses they considered. For this analysis each coder, counted the number of hypotheses mentioned in the essays. Since this was a simple count of the number of hypotheses explicitly mentioned in each essay, both the coders agreed on the number of hypotheses mentioned. No significant results were observed at the level of culture or at the dyadic cultural level.

Individual Essays: Participant's Perception of Study Partner's Divergence on Hypotheses

The second item in the essay writing instructions asked participants to describe how their hypotheses differed from those of their study partners. To analyze these subjective perceptions, a coding scheme of 5 categories of divergence was created (1=very different, 2=different, 3=slightly different, 4=similar, 5=very similar) for assessing participants' comparisons to their study partners' hypotheses. The interrater reliability for this analysis was high (*Kappa statistic* =0.87, *2-tailed p* <0.0001). A Kruskal-Wallis test of perception participant's perception of study partner's divergence on hypotheses was not significant with respect to culture or dyadic culture.

Individual Essays: Overall Agreement between the Two Participants

The third item of the essay writing instructions asked participants to state their conclusions and assess how they came to agreement or disagreement with their study partners. A coding scheme of 4 categories of agreement was created (1=no agreement, 2=partial agreement, 3=substantial agreement, 4=complete agreement) for assessing participants' statements about agreement/disagreement with their study partner on the final conclusion. The interrater reliability for this analysis was moderate (*Kappa statistic* =0.63*, 2-tailed p*=0.0001). A Kruskal-Wallis test of overall agreement was not significant with respect to culture or dyadic culture.

Individual Essays: Latent Semantic Analysis of Pair Agreement

Latent semantic analysis (Landauer, Foltz, & Laham, 1998) was done on the two individually written essays of a collaborative learning session. Specifically, pair-wise comparison each of the two essays of the 30 experimental sessions was conducted within the topic space of CSCL with 300 factors. Thus, we obtained 30 pair-wise agreement values for the 60 essays. A one-way analysis of variance of the LSA pair-wise agreement values with respect to dyadic culture (American-American, American-Chinese, Chinese-Chinese) was not significant.

Discussion

Any medium of interaction will provide a set of potentials for action, but it is up to the actors to decide which potentials are taken up, and for what purposes. Furthermore, the meaning of actions in a technology medium is negotiated interactionally—implicitly and/or explicitly. The results for RH1-RH3 provide initial support of the claim that representational guidance is culturally relative. The results on RH5 and RH6 show this negotiation is also influenced by cultural communication contexts of the actors. Results for *research hypothesis 1* suggest that cultural considerations should inform the design and implementation of referencing functionality in socio-technical environments. Indexical expressions (Garfinkel, 1967) and embedding artifacts in discussion both vary across cultures. For *research hypothesis 2*, the observed effect was exactly opposite to the theoretical prediction; American participants appropriated more affordances for evidential relation linking of knowledge map objects. One interpretation of the result is that if Chinese participants consistently perceive relationships between objects then there is little benefit to represent those relations externally and incur interactional labor costs. On the other hand, if the American participants attend to individual objects then they need to appropriate representational affordances to "reify" evidential relations as external representations. In other words, persistent perception of relationships might be necessary and sufficient for interactional purposes. However, there is no direct empirical evidence to support this interpretation. Further empirical studies might confirm or reject this interpretation. *Hypotheses 3 and 4* concerning threaded vs. embedded discussions has mixed results. These results suggest that the relative advantages of linked versus embedded discussion (Suthers, 2001a) might also be culturally relative. Significant findings on *hypotheses 5 and 6,* about explicit discussion of information sharing and knowledge-map organization strategies, respectively, have important consequences for collaborative applications. If task performance depends on information sharing that is to be accomplished primarily through social interaction then this study's results, like those of (Setlock, Quinones, & Fussell, 2007), suggest that interaction designers should incorporate prompting protocols or scripts for participants from high-context communication style cultures.

Despite differences between the two cultural groups on (a) how they used the tools and resources of the learning environment and (b) how they related to each other during and after their collaborative learning interactions, individual learning outcomes analysis of the essays indicated no significant differences. Put differently, interactional process differences during the collaborative problem solving session on how participants (a) used the tools and resources of the learning environments, and (b) related to and formed impressions of each other (Vatrapu, 2007, 2008; Vatrapu & Suthers, 2009) are not accompanied by learning outcome product differences in the individually written essays. Recall that the software design included multiple alternates for individual action and interaction. Participants interacted through an asynchronous computer interface providing multiple tools for interaction (diagrammatic workspace, embedded notes, threaded discussion). One interpretation of the individual learning outcomes results is that participants utilized the "alternates for action" incorporated into the learning environment effectively and appropriately from their own cultural standpoints, so they learned equally well. For example, Anglo-American participants created more evidential relation links, made more individual contributions, and were more likely to explicitly discuss information sharing and knowledge organization strategies than their Chinese counterparts. However, as mentioned earlier there are no individual learning outcome differences on the essays. Information sharing is necessary for joint problem solving in an asynchronous learning environment but it might be insufficient to account for learning outcomes (Suthers, Medina, Vatrapu, & Dwyer, 2007). The results of the experimental study hint at the existence of multiple interactional pathways to learning outcomes in intra- and inter- cultural computer supported collaborative learning. However, more systematic empirical work is needed to (a) establish the existence of and (b) evaluate the efficacy of multiple cultural interactional pathways.

Implications for Design

The empirical evidence from this study indicates that the informational focus of natural language communication and real world interaction of Anglo-American participants (low-context communication style) carries over to the online interactions. Both technology designers and instructional designers can incorporate this understanding into their practice. Chinese participants' preference of embedded discussion compared to threaded discussion has implications for practitioners of online courses and asynchronous learning networks that still predominantly use threaded discussion boards. It could be the case that the socio-technical affordances of current hierarchical tree structured threaded discussion boards vary systemically across cultural dimensions. Although the cognitive embeddedness of discourse and knowledge-building have been theorized and empirically evaluated (Suthers et al., 2008), social engagement and cultural embeddedness aspects of these design implementations have remained unexamined so far. Instructors and designers of online courses need to consider incorporating relatively more embedded forms of discussion than the threaded discussion boards. They need to consider ways of facilitating the varying degrees of social and cognitive embeddedness in a multi-cultural online classroom setting by using scripts and scaffolding. The results of this empirical study also suggest that instructional and organizational technology practitioners and designers need to recognize and facilitate both the individual and collective modes of contributions. Given that both seminal networked learning research (Hiltz, 1994) and current online learning best practices prescriptions (Moore, 2006) emphasize student collaboration, and since these aspects vary across cultures in traditional classroom settings (Hofstede, 1986) as well as online learning settings (Edmundson, 2007), mono-cultural design assumptions that do not incorporate diverse "alternates for action" might not achieve the best results in terms of student learning processes, outcomes and satisfaction.

Future work

In order to exhaustively study the potential effects of culture on the appropriation of potentials for action and the negotiation of the meaning of those actions, one needs to analyze individual actions in the context of their interactional sequences (Jordan & Henderson, 1995). Proposed future work includes microanalysis of this experimental study's data set. Combining the computational architecture of the mind, representational guidance, and Gibson's theory of affordances (Gibson, 1979; Wells, 1998, 2002), this micro-genetic analysis program will investigate how *cultural code, ecological data* and *interactional structure* intertwine to account for social interaction as appropriation of socio-technical affordances and the emergence of technological intersubjectivity.

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Beyond Explicit Feedback: New Directions in Adaptive Collaborative Learning Support

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Abstract: Adaptive collaborative learning support (ACLS) may be better than fixed forms of support at increasing learning from collaboration. While much existing adaptive assistance has focused on providing explicit feedback directly to the relevant student, we propose a two-dimensional design space which explores alternative methods of adaptive assistance that are implicit, indirect, or both. We investigated the viability of these ideas using data collected in a classroom evaluation of an ACLS system for peer tutoring which incorporated the design ideas in a manner that provided cognitive support to peer tutors. In this paper, we discuss how students interacted with the different forms of feedback, and propose a second iteration of the assistance that involves collaborative support in addition to domain support.

Introduction

Collaborative activities have been shown to be a good way of improving student learning, but effects are not found when students do not interact in positive ways (Lou, Abrami, & d'Appolonia, 2001). Thus, researchers implement collaboration scripts, which support student interaction using clearly defined roles and activities (e.g., O'Donnel & Dansereau, 1992). Most script support for collaboration that has been implemented so far has been *fixed*, and do not change based on student behavior. *Adaptive* support, which would provide assistance to students when and where they need it, might improve upon or complement many fixed forms of support (Rummel & Weinberger, 2008), and has indeed been shown to have a more positive effect on student learning (Kumar, Rosé, Wang, Joshi, & Robinson, 2007). However, few full systems have been implemented or had their learning effects evaluated (see Soller, Jermann, Muehlenbrock, & Martinez, 2005, for a review).

One potential reason for the slow progress in the field is that much adaptive collaborative learning support (ACLS) follows an individual learning model established in intelligent tutoring technology (see Van Lehn, 2006). Student collaboration is compared to a model of ideal collaboration, and discrepancies are addressed by providing *explicit* feedback on the next course of action *directly* to the student who is collaborating suboptimally (Soller et al., 2005). For example, COLER (Constantino-Gonzales, Suthers, & de los Santos, 2003) provides explicit advice to nonparticipating students such as, "George, participation is a learning opportunity. I suggest that you leverage it. Come on, participate! :)". Similarly, COLLECT-UML (Baghaei & Mitrovic, 2007) provides individual feedback on a UML modeling task such as "Some relationship types (associations) in your individual solution are missing from the group diagram. You may wish to share your work by adding those association(s)/discuss it with other members." This type of feedback might not be the most effective way of supporting collaborating students, as it favors cognitive processes without attending to social interactions, potentially distracting or overloading students. In fact, Kumar and colleagues (2007) found that students tended to ignore adaptive prompts while collaborating. Thus, it might be productive to explore the effects of other forms of feedback on student interaction and learning.

In this paper, we outline a design space for adaptive feedback involving two dimensions: whether the action that students should take is explicitly described in the feedback or implicitly arises as a result of the support (*explicit* or *implicit*), and whether it is presented directly to the person it targets or presented indirectly to another party or through a change in the learning environment (*direct* or *indirect*; see Figure 1). So far, most ACLS systems have been located in the lower right quadrant of Figure 1. We intend to further explore the possibilities for adaptive support by investigating a design idea in each of the other three quadrants.

1. *Adaptive Opportunities* modifies the learning environment in order to create learning opportunities for students. For example, problems could be adaptively assigned to students based on their previous interactions. Here, the change to the learning path is implicit, and feedback is presented indirectly.
2. *Peer-Mediated Feedback* encourages students to better self-regulate their learning. For example, if one student is not explaining a step clearly, we can prompt their partner to ask, "What do you mean by that?" rather than telling the first student to expand their explanation. This approach is indirect, as it is not presented directly to the relevant student, but explicit because the next course of action is clear.
3. *Adaptive Resources* provides resources to students at moments when they need them. For example, a video related to a given concept could be presented when a student may be thinking of applying the concept, and additional materials surrounding the video could incorporate specific information about the current problem or collaborating students. Here, the presentation of the resources is directly to the relevant student, but the course of action is implicit.

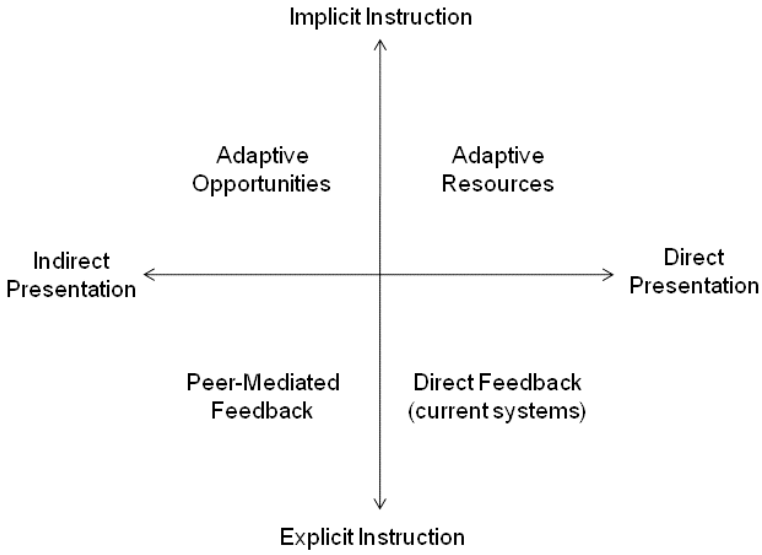

Figure 1. Design space for adaptive collaborative learning support.

We explore the viability of each idea using data collected from an existing adaptive collaborative learning system for peer tutoring, APTA (Adaptive Peer Tutor Assistance). APTA is an extension to the Cognitive Tutor Algebra, a successful intelligent tutoring system for individual learning in Algebra (Koedinger, Anderson, Hadley, & Mark, 1997). Using APTA, students take turns tutoring each other; the *peer tutee* solves the problem, and the *peer tutor* marks steps right or wrong, and gives the tutee hints and feedback in a chat window. In turn, the tutee can ask for help and self-explain. The system provides fixed domain support (the peer tutor can view a worked-out problem solution) and adaptive domain support (if the peer tutor marks something right and it is actually wrong, the system will intervene with a prompt to collaborate and a cognitive hint). We evaluated APTA in a classroom study that took place over the course of 2 weeks with 51 collaborating students (Walker, Rummel, & Koedinger, 2008), and the examples and observations addressed in this paper were drawn from that study. Each design idea has been realized to differing extents in the domain help provided by the system, enabling us to learn about how collaborating students might respond to the design ideas. We further discuss the implications of the initial results for further development of the designs.

Designs for Collaboration Support in the Context of APTA

Adaptive Opportunities

The current implementation of this design idea within the context of APTA is somewhat reflected in the adaptive instructional support delivered by the tutoring system, which attempts to set up opportunities where both parties reflect on and repair their misconceptions. To accomplish this goal, the system compares each peer tutor assessment of tutee actions to the cognitive tutor assessment, and makes peer tutors aware of discrepancies that arise. Table 1 illustrates an example from our study where the tutor marked a problem step correct, but then was presented with information from the intelligent system which demonstrated that the step was in fact incorrect. The peer tutor determined how to repair the error and take the next correct step. Although the outcome of his reasoning was communicated to the tutee, the process itself was not made transparent, potentially explaining why the delayed gain of the tutor was 0.375, while the tutee showed a delayed gain of 0.125. In general, tutors appeared to benefit even from simply viewing tutee errors.

This design idea might more usefully be applied in creating the opportunity for errors to be committed through the adaptive selection of problems that lead to errors. There were two obstacles preventing errors from being committed by the tutee. First, many problems were too easy for tutees. Second, some peer tutors were overzealous in helping tutees, such that tutees had no chance to commit errors. We would see a pattern where a given tutor would give the tutee an instruction like "factor q", the tutee would execute the action, and the tutor would immediately give the next instruction like "divide by a + b". Therefore, our next step in implementing this design idea is to create the conditions where errors are made. As in the individual version of the CTA, we plan to assess the skills that tutees have mastered, and adaptively select problems where tutees are likely to make errors that both parties can benefit from. Simultaneously, we will assess the peer tutor tendency to provide unsolicited help before a step has been attempted, and, if it is high, select problems for the tutee that the peer tutor has not yet mastered. Hopefully, if the peer tutor is struggling with the concepts in the problem, he or she will be less able to simply walk the tutee through the problem, and more joint knowledge construction will occur. This intervention is potentially advantageous because of its subtlety; students are unlikely to notice the deliberateness of it, but it has the potential to increase the opportunity for tutees to make errors and therefore the potential for learning. Adaptively selecting problems to improve learning conditions is an example of guidance with an indirect presentation, as it is not directly delivered to the student, and implicit instruction, as it does not make the next interaction steps clear to students.

Table 1. Learning opportunity created by tutee error while solving the equation "3q-xq = x."

Step Description	Analysis
Tutee selects "factor q", but types "3q = x".	The tutee knows what to do, but is not sure how to complete the step.
Peer tutor approves the calculation, and receives error feedback from the cognitive tutor.	The peer tutor initially thinks the step is correct, but is made aware from the system that it is an error, creating a learning opportunity.
The peer tutor tells the tutee "undo that step", but the tutee proceeds by dividing by 3. The tutee clicks the done button, but the peer tutor disagrees.	The peer tutor understands that the tutee has not solved the problem.
The students have the following exchange: Peer tutor: undo it Tutee: why? U marked it right? Peer tutor: the step is right but it said you made a typing error when you factored The dialog continues until the tutee confirms which step to undo.	The peer tutor identifies the error for the tutee in an unelaborated way.
The tutee undoes the step, and the tutor explicitly tells the tutee what to do, after asking for a hint: Now factor out q. It should be q(3 – x) + x. q(3 – x) = x, sorry	The peer tutor then tells the tutee how to complete the step, correcting his own error.

Peer-Mediated Feedback

The current implementation of peer-mediated help in our system lies in the way assistance was presented, where error feedback and hints on *tutee* problem-solving actions were presented to the peer *tutor*. We hoped that the peer tutor would elaborate on the help and adapt it to the tutee's needs, improving the learning of the tutee. Below, Table 2 contains an example drawn from a different pair than Table 1. The peer tutor is told that they are not actually done with the current problem, and then more successfully communicates hint feedback to the tutee than the peer tutor from the previous example. In this pair, the tutee had a gain score of 0.375 on the delayed posttest. Here, the tutee benefitted from committing an error and engaging in a dialog with the tutor.

Table 2. Example of peer-mediated feedback. Students are solving for *t* in the equation: t = (-bh+mn)/(-v-r). They need to simplify the equation.

Step Description	Analysis
Tutee selects the done button. Peer tutor incorrectly agrees, and receives feedback from the system.	Both students are surprised to hear that they are not done.
The tutee says, "do u kno wat i should do". The tutor looks at the problem solution.	The tutee asks for a hint, and the tutor consults the worked example to help her.
Students have the following dialog: Tutor: look at the neg sign on the denominator Tutee: but wat do i do to get rid of the negative? Tutor: the neg has to disappear u ll find it in trans Tutee: will u please just tell me already? Tutor: i don't remember what it's called The dialog continues until the tutor realizes that he does not actually know the specific next step.	The tutor begins to give elaborated help, but lacks the knowledge to fully identify and explain the step. The tutor is unsuccessful at helping the tutee.
The peer tutor asks for a hint from the cognitive tutor. She communicates the help, saying "use common factor". The tutee simplifies fractions and then promptly undoes it. The tutor says, "-1" , and the tutee factors -1. Finally, the tutor says, "now simplify." The tutee simplifies and completes the problem.	The peer tutor uses a hint to provide a series of procedural instructions to the tutee. The tutee successfully completes the problem.

This example illustrates an additional place for implementing peer-mediated feedback. One difference between the examples in Table 1 and Table 2 is that the peer tutor in Table 2 attempted to explain the error, which was less the case in Table 1. Often, even when peer tutors transferred the system feedback they received to the tutees, they did not elaborate sufficiently on the feedback. Therefore, we propose to use "reverse" mediated feedback to the tutee in order to encourage tutors to produce better explanations. For problem steps where tutees receive help from the tutor, and it is likely that they do not understand the concepts involved with the help, we plan to deliver indirect explicit feedback to the peer tutee such as: "Wait -- do you understand why you should subtract *x*? If not, ask your partner why." This approach is in contrast to a direct and explicit feedback approach, where the prompt would generally be given to the peer tutor: "Why don't you tell your partner why they should subtract *x*." In this proposed "reverse" mediated feedback, it is not so clear that blocking other tutee actions (e.g., problem-solving actions) as they receive this feedback is the best direction, as it takes away some tutee control over their environment. How to balance student control with partner confusion is still an open question. Nevertheless, we envision that this mediated feedback will promote better self-regulation of the collaborative learning and potentially trigger a deeper interaction.

Adaptive Resources

Another attempt to help peer tutors provide good advice to tutees was by providing them with a worked-out solution to the problem in the interface. As an implementation of the *Adaptive Resources* design idea, this approach is limited, because the resource (the problem solution) did not change during problem-solving. However, looking at how students used this fixed resource might give us better insight into how tutors might benefit from an adaptive resource. Students appeared to use the problem answers in two ways: to check the work of their partner and to figure out the next problem step. In fact, the problem solution was consulted frequently in the course of regular problem-solving so that the peer tutor was always prepared to give help. Thus, we see an opportunity here to adaptively present resources in order to encourage deeper conceptual interaction amongst the students. In the process of comparing the tutee actions to the problem answers, some tutors were able to generate help that contained conceptual information, suggesting that they were engaging in beneficial knowledge-building processes. Table 3 is an example of a conceptual exchange observed between students, where the peer tutor involved had a gain score of .625 on the delayed test. Although this exchange is the type of interaction we were hoping to see, this kind of conceptual help was rare among students.

Table 3. Conceptual interaction about problem ay + by + m = n

Step Description	Analysis
The tutee factors *y*. The tutor checks the problem answers (which say to subtract *m* from both sides). The tutor marks the problem step wrong, and the tutee undoes the step.	The tutor (incorrectly) flags the tutee because her solution doesn't match the problem-solving action
The students have the following dialogue: Tutor: ok um what variable is by itsself Tutor: that is the one you need to get on the other side Tutee: right now just "n" but i have to get "y" by itself Tutor: look at the equation ay+by+m ...wat 1 is bby itself Tutee: m	The tutor conceptually explains the first step as she sees it.
The tutee adds *m*. The tutor gives a hint: Tutor: look at the sign b4 n	The tutee makes a conceptual error, and the tutor immediately moves to correct it.
The tutee combines like terms. The tutor checks the problem answers and flags the step. The tutee undoes both steps.	The tutor uses the fixed resource to verify her thinking, then marks the step wrong.
Tutor: look at the sign b4 the m is it a plus or a minus Tutee: it a plus so i would wnt to minus it from the rest of the problem	The tutor continues giving the conceptual hint. The tutee self-explains her reasoning.

We intend to explore two types of adaptivity in delivering resources to students: Changing the content of the resources based on the current problem state, and changing the content of the resources based on an assessment of student knowledge. There are several different types of resources we can provide to peer tutors other than a worked out problem example, arranged in order from most general to most specific:

R1. Conceptual description of how to solve the problem rather than the problem steps
R2. Example of a similar problem, but using numbers in place of letters representing constant terms
R3. An annotated worked-example with conceptual explanations for each step

Different levels of help might be appropriate at different times in the problem: The earlier resources might be better for tutees who have mastered the skills necessary to solve the problem or have not made many attempts at the problem step, while the later resources might be better for students who have made several incorrect attempts or are not expected to have the skills required for the problem. Additionally, the content of the resources themselves could be adapted based on information about the current problem-state, skill mastery, or student interaction. For example, R2 could also display the errors made by the tutee on the problem using numbers in place of letters, or R3 could derive the conceptual explanations using language that students have used previously. Making the resources adaptive means that we can provide peer tutors with a wide variety of different resources over the course of the activity without overloading them, and we can tailor the presentation of each resource to the particular problem situation and to the abilities of the tutee.

Discussion

In this paper, we have outlined a design space for the delivery of adaptive feedback to collaborating students, focusing on two dimensions: the explicitness of the feedback content, and the directness of the feedback presentation. The three ideas that we have generated, each falling into a quadrant of the design space, are not incompatible with direct feedback, nor are they incompatible with each other. It is likely that each idea is best applied in particular contexts, and multiple feedback types should be integrated within a single system. In APTA, it makes sense to use adaptive opportunities to create an amount of errors sufficient for the peer tutor to benefit from the interaction, mediated feedback to encourage tutors to generate explanations rather than instructions when tutees make errors, and then adaptive resources to help peer tutors put conceptual elements into their explanations. In the cases where one feedback type doesn't work, a second feedback type might be more appropriate; for example, if mediated feedback isn't being communicated, it would seem natural to switch to direct feedback. Determining when and how to apply each kind of feedback is still an open research question, with the ultimate goal of optimally facilitating computer-supported collaborative learning interaction.

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Negotiation-Tools in CSCL-Scenarios - Do they have a valid use?

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Abstract: Within discursive knowledge construction, students are expected to negotiate within their collaboration as soon as they face opinions, concepts, or meanings differing from their own. Therefore, negotiation has become a central issue of CSCL research. In an experimental field study with 16 groups of 3 individuals each, we examined whether the demand to use technically supported communication (e-negotiation) within an asynchronous and spatially distributed setting has a positive influence on group discussions and knowledge integration. Our results indicate that the implementation of e-negotiation is in fact advantageous, but does not automatically lead to a successful result. Employed intensively, e-negotiation allows group members to emphasize incompatible ideas and therefore offers advantages especially in creative problem-solving processes.

Introduction

One of the most crucial challenges within asynchronous CSCL is the encouragement of students to refer to each other and to their contributions. In discursive communication (Herrmann & Kienle, 2008) referencing to the concepts of others indicates the degree of collaboration (Stahl 2003) in contrast to situations where a number of students work on the same problem but in solitude. Within discursive knowledge construction, students are expected to negotiate within their collaboration (Dillenbourg, 1999) if they are faced with opinions, concepts or meanings which differ from their own. Therefore, negotiation has become a central issue of CSCL-research. Negotiation is the process where differing perspectives are related to each other and where a convergence between unconnected or incommensurable ideas is pursued in the course of decision making. Negotiation is especially relevant in the case of problems or tasks where the solution is not determined in advance and where a wealth of ideas and contributions is needed to find a good solution by building synergy and pursuing convergence.

Negotiation can be a subject of analytical work as well as a focus of intervention strategies. From an analytical viewpoint, the negotiation of the meaning terms or concepts is observable. Moreover, it can be observed that a breakdown experience (Stahl, 2000) with respect to mutual understanding leads to negotiation. The negotiation of meaning is considered as a fundamental basis of the development of mutual understanding and sense making. Therefore negotiation can be an analytical category which helps to detect the occurrence of mutual knowledge construction.

On the other hand, negotiation can be an orientation for intervention strategies which foster collaborative knowledge construction. Conversation schemes or scripts (e.g. for argumentation) can be offered or prescribed to guide the way in which students relate their contributions to each other. Furthermore, the technical features of CSCL can be designed to provide a scaffold which represents the guidance through the conversation schemes. The guidance can be focused on the type and sequence of conversational chunks (such as pro- and contra-arguments) or on the support of decision making, e.g. by offering a voting mechanism.

We have developed CSCL-prototype called Kolumbus2 (Herrmann & Kienle, 2003) which is strictly oriented towards the support of interactive, mainly asynchronous communication and the conveying of the context which completes the communication processes. This prototype includes a negotiation-function which completes the work with shared material and the annotated conversational threads with possibilities for voting; votes can optionally be commented upon by the voters. The basic assumption behind this feature is that the availability of negotiation support together with a clarification about how to use it has a positive impulse: The students of a learning group are asked to make a decision in the sense that they all agree to be co-authors of certain statements which represent the shared results of the group. It is assumed that this decision making promotes a phase of convergence in which the multiplicity of divergent ideas, which are produced in the context of thought provoking tasks, are integrated. The Kolumbus2 prototype was tested in several practical cases. These case studies revealed that the negotiation function was used and accepted. Several improvements were proposed by the participants. It became clear that the usage also depends on the planning of the collaboration process and on the influence of a facilitator (Carell et al. 2005). However, up to this point we had had no insights into whether the negotiation and voting process just led to some non-reflected pragmatic decisions or whether they were accompanied by deliberate knowledge integration. We assume a positive effect from the voting-based negotiation procedure: those students who have to make a decision between “accept” or “reject” may be motivated to develop a clear understanding of how their own ideas are related to those of others. They will be able to identify those contributions which provoke the most divergent reactions. The students attempt to overcome this divergence may result in a higher degree of convergence. To validate these assumptions, we designed an initial experiment with 16 groups, each made up of 3 participants, to achieve first results whether the degree of convergence is influenced by the request to use a negotiation tool and whether it can be measured. On the basis of this initial experiment it is possible to describe the requirements for the underlying task, the procedure, the instructions and the underlying hypotheses have to be specified within an ongoing investigation of the relationship between knowledge construction, and the availability of negotiation functionality. One of the crucial questions is whether the availability of a negotiation tool really does promote convergence and knowledge construction or whether it is just a means which makes it possible to systematically observe that those students who are willing to negotiate and to integrate their knowledge are using this functionality.

The following section gives an overview of related results of research on negotiation in the context of CSCL. The third section describes the experimental design. It is followed by a description of the results and the concluding discussion.

Research on negotiation and the consequences for negotiation-support

One of the most detailed overviews on the roots and relevance of negotiation is given by Stahl (2003) who refers to the background of negotiation within CSCW and to the underlying concepts of collaborative learning. Within CSCW-research, negotiation is mainly important for Group Decision Support Systems (GDSS, deSanctis & Galuppe, 1987, Vogel et al., 1987) and is usually accompanied by possibilities for voting which allows the users to prioritize their favorite options within a set of available choices. Stahl contrasts this kind of decision making with the role of negotiation within theoretical frameworks of collaborative learning such as the small group process, social constructivism, distance education, distributed problem-based learning, distributed cognition, cultural-historical activity theory. He outlines that negotiation has its relevance within these theoretical approaches with respect to knowledge building. He concludes that "the concept of negotiation as voting seems inadequate for CSCL. In particular, the negotiation of what is to count as new shared knowledge for a group engaged in collaborative knowledge building has different characteristics from other forms of group decision making" (Stahl 2003). We comply with this suggestion since we emphasize that the process of voting itself is not the arena of negotiation but the accompanying discussion threads. Therefore a voting mechanism has been combined with the possibilities for commenting and for annotated discussion threads of Kolumbus2. We call the type of negotiation, which is triggered by the request to accept or reject a proposal, e-negotiation. The design rational is that repeated voting, which is suggested to the students, is a trigger which increases the degree of knowledge sharing and integration. The experiment which is described in this paper is a first attempt to validate this assumption.

Within his review on negotiation research, Stahl (2003) also analyzes the strengths and weaknesses of an early version of Kolumbus2 (Stahl & Herrmann, 1999). Based on his analysis, he developed another negotiation-supporting CSCL-system: BSCL. Kienle (2007) has conducted several case studies to understand how negotiation support has to be designed, and she (Kienle, 2007) compares BSCL with Kolumbus2 with respect to practical experience and user feedback. The improved negotiation mechanism of the current version of Kolumbus2 refers to Kienle's work. A specific feature of Kolumbus2 is that the result of voting leads to an automatic activation of certain functions by the system. This approach was developed together with Wulf, Pipek and Pfeifer (2001), who have focused their work on negotiation between two roles, where – for example – one person requires a certain access right and the other person can agree to it or reject it. If the negotiated item such as a piece of text or a document is accepted, Kolumbus2 changes its status in accordance with the proposal which has been made by the initiator of the negotiation. Possibly, a new version of the item is stored, the group of recipients (who can read it) is enlarged or new co-owners are added. Co-ownership (Prilla & Ritterskamp, 2006) is the typical way of documenting so that several students consider an item within Kolumbus2 as their shared contribution.

The early work of Dillenbourg and Baker (1996) on negotiation spaces was not taken into account for the development of Kolumbus2. However, our approach complies with their requirements to support symmetrical interaction and to be aware of various dimensions such as the degree of flexibility, systematicity etc. Another CSCL-discourse deals with the phases and sequences into which negotiation is embedded or consists of. These phases can either be used as categories which help to analyze CSCL-based discourse, or they can be used to define scripts which are implemented into the system to scaffold the students' interaction. An influential contribution was made by Gunawardena et al. (1997), who provide an interaction analysis model with five phases: statement and application of newly constructed knowledge, testing, negotiation, dissonance, sharing and comparing. Beers et al. (2005) refer to five other but similar negotiation primitives: contributing, verifying the understanding of another's contribution, clarification, acceptance/rejection of a contribution and explicitly stating the own position on a contribution. These primitives serve as a basis for a negotiation tool that "… coerces the users into exploring each other's perspectives to augment the negotiation of common ground (Beers et al. 2005, 625)." The tool was tested in an experiment. It was assumed that coercion leads to a higher number of negotiations per contribution. However, the control groups produced an even higher number of contributions. This observation correlates with Dillenbourg's (2002) reasoning on the problems with over-scripting.

The Kolumbus2-protoype does not apply any scripts but offers a high degree of flexibility since we do not want to test the effects of scripting but of weaker types of intervention which combine the offer of certain functions with the suggestion to use them. We differentiate between three phases (Herrmann & Kienle, 2003): 1) work with one´s own material and research results, 2) work with the material and results of others and 3) collaboration which includes threaded discussion and negotiation. The phases are not sequenced but the students can flexibly switch between them. Also, the negotiation-function is designed with a high degree of flexibility with respect to the dimensions which are displayed in Table 1.

Table 1: characteristics of CSCW-related negotiation - general and KOLUMBUS (Kienle & Herrmann 2004)

characteristics	general (KOLUMBUS)
aim of negotiation	relevance or appropriateness of data, decision about further activities, decisions about the configuration of the system, joint editing decisions
types of proposals	access rights, authorship, editing functions (insert, copy, paste), rating, …
no. of participants	> 1 (ca. 5 – 20)
discussion and commenting	discussion threads related to votes, proposals or to the negotiation process as a whole
options of voting	accept, reject, abstain, counter proposal, "Lets talk"
visibility of voting	Secret vs. comprehensible, anonymous vs. assigned to persons, statistical information about the negotiation process vs. result oriented information
mode of voting	One vote per person per proposals vs. votes can be repeated and changed

Figure 1. Screenshot of the negotiation-tool

Voters can be allowed to flexibly alter a) their votes during the negotiation's time span, b) the negotiation deadline, and c) the recipient of the negotiation (only at the beginning but not during the negotiation process). Votes can be commented on and the comments can be continuously extended. Therefore, voting and discussion threads are highly interwoven. The negotiation is started if a participant tries to activate a function which affects the right of others. For our experiment, we referred to the function which converts others into co-owners of a textual statement. The explanation of the co-ownership clarifies that co-owners have to identify themselves with the meaning and the content of the co-owned statement – they agree with a kind of co-responsibility for the content. If some-one invites others to become co-owners, a negotiation is started (see Figure 1). Those who are invited have the right to accept or reject the invitation or to abstain. The initiator's proposal is counted as an accept-vote. The vote can be altered but the negotiation proposal cannot be withdrawn (in distinction from BSCL, Stahl 2003) since we want to avoid the votes and comments made by others being deleted and therefore not valued. The diagram of Figure 2 gives an overview of the possibilities of the negotiation procedure.

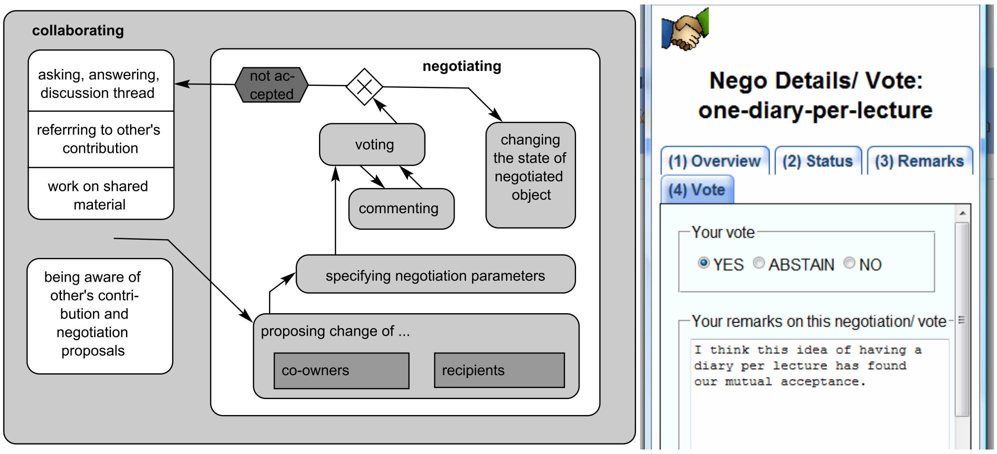

Figure 2. Possibilities of the negotiation procedure

Experimental field study

In the following we present the quasi-experimental field study carried out by us. Here we understand this study as an "explorative study of an experimental nature" which should contribute to an empirically proven formation and precise explanation of hypotheses within the area of investigation.

Aim and assumption of the study

The aim of the study was to find out whether the offer and demand to use technically supported negotiation (e-negotiation) within an asynchronous and spatially distributed problem-solving process leads to

- groups bringing together and integrating their discussion processes better (assumption 1). Investigations show, for example, that virtual groups have hardly any problems collecting their ideas within the framework of brainstorming. The difficulties lie, above all, in the next phase of convergence formation where it comes to the systematic selection of the compression or intertwining of ideas. Not least due to time pressure, a good idea will often suddenly be accepted as "the solution" without a unanimous group consensus being reached (see Carell 2006).
- a more transparent and more easily recallable group result (assumption 2).
- a more homogenous individual perception of the group result (assumption 3). Especially with asynchronously lead discussions, those studying will often receive the contributions of others insufficiently, do not have them present and can accordingly only insufficiently incorporate them into their own formulation or into the description of the group results. It is much more usual that the participants´ contributions stand together unconnected. We assume that an explicit computer-supported negotiation process enables students to become more intensively familiar with the negotiation content which in turn becomes more current to them before they react to it.

Furthermore, we assume that the demand to use e-negotiation provokes a more controversial yet focused discussion (assumption 4). At the same time, we wanted to determine within the framework of a qualitative evaluation used during the course of the group discussion at which points e-negotiation can be started and what effect this has upon further discourse (question 1).

Setting and Data Collection

Setting

To examine the afore-mentioned assumptions, we carried out an experimental field study from June 2007 to October 2007. The study took place in two waves. In total 48 individuals voluntarily took part in the experiment (28 male and 20 female). For this experimental field study the following setting was organized:

- *Groups*: 18 groups, each comprising 3 individuals, were formed. Each of the 18 groups was formed by first assigning a person with deep knowledge of the learning system being used (www.kolumbus2.de) and who, in the role of "power-user", was available to answer questions regarding the use of the system. Second, the other group members were randomly assigned. As more males than females took part in the experiment, a weighting of men and women during random selection was not deemed necessary. All participants had been made familiar with the learning environment Kolumbus2 through a one hour introduction. Table 2 shows an overview of the male / female grouping. Two groups were not included in the evaluation because one member in each group neither took part in the communal group project, nor filled in the final questionnaire. Therefore, the evaluation of the experiment relates to a total of 16 groups.

Table 2: Group formation according to gender

	1 female 2 male	2 female 1 male	3 female 0 male	0 female 3 male
Number of groups	5	6	1	4

- *Task*: The group, made up of 3 individuals, received the task to look at the website www.pepysdiary.com and to develop together a concept on how its essential idea could be transferred to university teaching events. Pepys, on whom the website is based, lived in 17th Century London and kept a diary over many years. Every day, one page of the diary is published on the internet site. The first entry in the diary from 1st January 1660 was published on the 1st January 2003 and every day since, a new entry has been published. To complement the diary site there is also an encyclopedia which contains historical facts about people, places, things and events, more in-depth articles about specific aspects of Pepys´ diary, as well as information on the latest activities of the internet site etc. Therefore Pepy's diary has developed into a successful learning environment. The task for the participants in the experiment was to make a proposal of how elements of this example can be transferred to improve the organization or electronic support of university courses. This task was chosen as such because there is no pre-defined solution which one can find or name. Through this, a higher variety of expected results or contributions was produced, which, in turn, leads to the chance being higher that the contributions are firstly heterogeneous and only converge later on in the process. For this experiment, it would not have been appropriate to set a task which produced homogeneous contributions from the start. One intervening factor which should be noted here is the influence of the used system – in this case Kolumbus 2. Such a system can, in the context of our chosen task scenario, lead to a common context or framing within which the contributions relate to each other and therefore become more uniform.
- *Time frames and quantitative participation*: the participants were given a total of 12 days to work on the task. Within the framework of the introduction to the experiment, the participants declared themselves prepared to log onto the system at least once a day, to take note of the others´contributions and to leave their own "trace" in the system.
- *Experimental Conditions*: the experiment was carried out under two conditions. Groups with condition 1 were explicitly instructed to use the electronic negotiation tools in the consensus formation process (condition "with offer of e-negotiation" abbreviated to "with"), while groups with condition 2 (condition "without offer of e-negotiation" abbreviated to "without") did not have the negotiation tool made available to them. The assignment of the groups to the conditions was random (in total 18 groups – 9 groups per condition). As two groups were not included in the final results (see GROUPS), there were nine groups with the condition "with" and seven with "without".
- *Instructions*: at the start of the experiment, the groups received their experiment instructions by e-mail. At the same time, the instructions were placed in the learning environment for everyone to see. As well as the afore-mentioned instructions for each experimental condition, the groups received instructions on organizational levels. To these belonged: the requirement to only carry out communication via the learning environment, to pass information on about how to start and to finish the participation in the experiment, to give hints on the organization of the process, to introduce themselves, to participate continuously as well as to inform the group members if a participation is not possible due to serious reasons.
- *Blind Interventions*: during the 12 day experiment, the experiment leaders had no access to the virtual group work areas and were also unable to access the system's logfiles. For this reason, blind interventions were sent to all participants via e-mail at pre-determined times. Table 3 gives an overview of these interventions.

Data collection and analysis

At the end of the experiment, the group work areas were closed to all participants. Immediately after the closing of the learning environment, all participants received an electronic questionnaire. This comprised, on one hand, questions on socio-demographic aspects, about familiarity with the learning environment Kolumbus2 and on experiences with collaboration within groups (virtual as well as face-to-face). On the other hand, they were asked to relate the elaborated group concept in their own words. These texts were then evaluated by six reviewers. The reviewers' task was to compare the participants' descriptions with respect to five aspects:

- The similarity of both most similar descriptions (related to core statements)
- The dissimilarity of both least similar descriptions
- The degree of general similarity (related to all three descriptions of each group)
- The degree of communality in the group concept
- The novelty content / originality of the concepts.

These types of questions were asked on the basis of the assumption, that similarities between the students' description are an indicator of the degree of achieved convergence and knowledge integration. Each reviewer examined each one of the 16 groups. The results were given on a scale of one to ten (1= very low to 10= very high). After the quantitative analysis, which was based on the answers of the reviewers, the qualitative analysis of the group discourse with and without the offer of e-negotiation was carried out.

Table 3. Overview of blind interventions

Time	Blind Intervention
After 30 hours experimental time (ET)	The participants were again advised of the specific instructions of each experimental condition. They were advised of the agreed participation frequency.
After 6 days (ET)	Participants were advised that half of the experimental time was up. They were also reminded of the task to produce a communal concept.
After 11 days (ET)	The last day of the project was announced. The instructions for the proper conclusion of the experiment were given.
After 12 days (ET)	The end of the experiment was announced and the learning environment was closed to all participants.

Results

Quantitative Analysis

Firstly, we compared the two experimental conditions („with offer of e-negotiation" vs. "without offer of e-negotiation"). This analysis reveals that the simple difference between offering and not offering an e-negotiation tool does not necessarily lead to clearly differing results. However, a detailed analysis of the group process reveals that the groups in the condition one "with e-negotiation" used the negotiation tool to varying degrees. Table 4 gives a detailed overview:

Table 4: Use of the e-negotiation tool under the condition "with offer of e-negotiation"

Group	14	16	12	6	10	9	13	3	8
No. of e-negotiations	0	0	1	1	3	5	6	7	12

Due to the fact that two groups with the condition "with offer of e-negotiation" did not use the negotiation tool at all, and two further groups only used it once, we conducted a second analysis which neglects the two empirical conditions and compared instead groups with 5 or more e-negotiations with groups which use e-negotiation less than 5 times. This detailed group comparison shows significant effects in mean differences between these two types of using the e-negotiation tool. In those groups' with five or more e-negotiations:

1. the number of single ideas received in the descriptions is altogether higher
2. the similarity of the 2 most similar texts is greater
3. the similarity of the 2 least similar texts is higher
4. the total similarity is greater and
5. a communal group concept is considerably more visible (see Table 5).

Qualitative Analyses

In the following we will investigate the question of how the e-negotiations initiated by the groups contributed towards the working and solving of the tasks. Based on all 16 groups, we simultaneously contrasted firstly those groups with five or more e-negotiations ("the frequent e-negotiators") with groups which had e-negotiated fewer than five times ("less frequent e-negotiators"). The essential results are summarized in the following:

- Chronological position of the negotiations: the less frequent e-negotiators negotiated only in the final phase of the concept formulation when the focus was on the final adoption of the group results. The concept negotiation took place communicatively without using the tool. By contrast, the frequent e-negotiators also used the e-negotiation tool in order to agree upon ideas.

- Completion of the negotiations: Table 6 classifies with which results the negotiations were finished. After that, the majority of the participants' initiated negotiations are accepted. The second most frequent completion of a negotiation is the "time out". This happens when the group members do not react to a negotiation within a given period of time. Only a small number of negotiations end with a rejection, and rejections only – with the exception of group 10 - occur in the group of frequent negotiators. Rejections are used by this group in order to discuss, to modify or to eliminate contentious aspects, with the aim of reaching a unanimously agreed upon group concept.
- Aim of the negotiations: the frequent as well as the less frequent negotiators use the tool above all to vote on aspects of content, and they try less to use it to clear up or solve organizational or process-related questions.

Table 5: Use of E-Negotiation – Group comparisons

	No. of e-negotiation < 5 N = 12		No. of e-negotiation ≥ 5 N = 4		Effect Size	
Variables	M	SD	M	SD	Cohens d	
V1 No. of ideas	4,19	1,22	5,38	0,57	1,11	***
V2 Similarity	6,93	1,47	7,63	1,19	0,50	
V3 Dissimilarity	6,63	2,32	4,23	1,31	1,17	***
V4 Total similarity	5,85	2,11	7,71	0,92	1,02	***
V5 Group concept	5,36	2,42	7,67	1,06	1,10	***

*** = strong effect. Due to the small sample size we measure the effect size of the founded mean differences by using Cohens d. (Cohen, 1988). Table 5 shows that strong effects occur in variables v1, v3, v4 and v5. Moreover, a look at standard deviation (SD) shows that the reviewers' opinions of those groups with more than five are more homogenous than those groups with fewer than five e-negotiations.

Table 6: Type of Completion of negotiations

Group	Accepted	Rejected	Time out	Sum of Negotiations	Content related	Process related
Group 3	1	3	3	7	7	0
Group 6	1	0	0	1	1	0
Group 8	5	2	5	12	0	2
Group 9	2	2	1	5	5	0
Group 10	2	1	0	3	3	0
Group 12	1	0	0	1	1	0
Group 13	3	1	2	6	6	0
Sum	15	9	11	35		

To gain further insight into the use of e-negotiation we secondly compared two groups with the condition "with" with two groups with the condition "without". In the condition "with" we chose the two groups with the highest number of negotiations, and in the condition "without", those groups who had the most successful discussion with respect to the total results (T) gained the highest total results of the variables shown in Table 5. The total results (T) are calculated as follows: T=v1 + v2 – v3 + v4 + v5 (see Table 5).

Furthermore, we contrasted the groups with regard to relevant conflicting variables. Table 7 shows that both groups with the condition "without" have significantly more experience with online discussion, that is to say, computer supported cooperative work than both groups with the condition "with".

Table 7: Comparison of selected groups

Condition	Group	total results (T)	Rang	Experience with…[2] Groupwork	Online discus.	CSCW[3]	Kolumbus2
			n = 16	m	m	m	m
With	Group 3	32,33	2,00	4,60	2,00	2,00	3,60
With	Group 8	31,67	3,00	4,00	2,30	2,30	2,30
Without	Group 5	31,90	1,00	5,00	4,00	5,00	4,00
Without	Group 1	28,67	4,00	4,60	3,30	4,00	3,00

[2] estimations on a scale of 1-5, 1= lowest value, 5= highest value; [3] Computer Supported Cooperative Work

In the group discussion processes there is a significantly divergent phase in three of the four groups in which ideas are collected. Furthermore, there is a convergent phase in which ideas are compounded and a communal solution concept is created. E-negotiations only occur in the latter-mentioned phase, which we will look at in further detail in the following.

Our qualitative analyses reveal that groups with the condition “with” use e-negotiation in order to negotiate a concept suggestion. Group 8 only produced and discussed individual results from the divergence phase in order to vote. Votes are assumed in the final phase, rejections are used to specifically discuss contentious aspects. On the basis of these discussions, these aspects are either modified or not included in the final concept. Group 3 reacts in a similar way. One member of the group makes a concept suggestion at the beginning of the convergence formation on the basis of the collected ideas. This is then rejected several times and then continually modified on the basis of the established detail discussions until the concept is finally accepted by everyone and becomes the group concept.

Group 1 with the condition “without” also develops their first concepts on the basis of the collected ideas in such a way that they take and amplify the different ideas from the divergent phase. During concept discussions, specific aspects are brought up and criticized by the participants. It remains, however, unclear whether this necessarily leads to the rejection of a suggestion. At the same time, comments as well as the opinions of individual participants are not mutually taken into consideration: the other participants frequently react to them with neither positive nor negative comments. It becomes significant that conflicting concepts are not weighed against each other, nor are they systematically linked together, but rather added together to form a concept. In contrast to the three groups already mentioned, group 5 hardly develops any divergent ideas. They start much more with one concept suggestion which is then systematically built upon and finally summed up to form the end concept. All in all, the group work in the condition “without” is characterized by strong harmony: controversial discussions are hardly present. Figure 3 visualizes and compares the discussion process of group 8 (condition “with”) and group 1 (condition “without”).

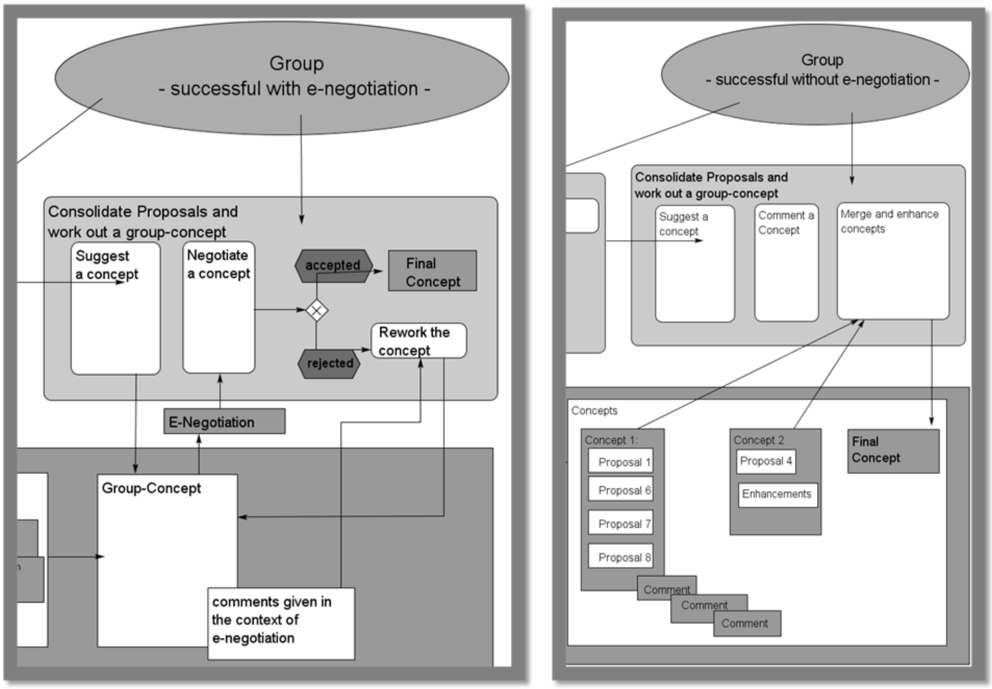

Figure 3: Differences in the convergence phase in the groups with the conditions “with” and “without”.

Discussion: What’s the use of negotiation tools?

The aim of our experimental field study was to find out whether the offer of technically supported communication (e-negotiation) within an asynchronous and spatially distributed setting on various levels and the appeal to use it had a positive influence on knowledge integration.

Our results indicate that the implementation of e-negotiation tools under certain conditions is, in fact, advantageous, but does not automatically – just by an appeal to use it – lead to a successful result. In our investigations, the effects are only strongly noticeable if the groups use e-negotiation at least 5 times. These groups provide more ideas, the two most dissimilar texts are more similar to each other than in the other groups, the total similarity of the indicated group concepts is greater, and a communal group concept is significantly recognizable. (Assumption 2 and 3 are empirically proven). However, we cannot clearly determine whether the positive effects are caused by employing the e-negotiation tool or whether the higher number of negotiations is just an indicator of a more intensive process of convergence and knowledge integration. It may be the case that some groups are more motivated and capable of integrating their knowledge because of unknown reasons – but our study reveals that these unknown reasons do at least lead to a higher number of e-negotiations. Furthermore, the other direction of cause and effect – i.e. the e-negotiation triggers knowledge integration – is still plausible.

The use of e-negotiation is reflected in our results especially in the convergence formation phase of the creative problem-solving process. In accordance with the findings of Barron (2003), groups with multiple negotiation as well as those without perform successfully in experiments. In the former, however, ideas and concepts are, on the whole, perceived more differentially. Differences of opinion start at the beginning and are specifically and discursively worked upon. (Assumption 1 is empirically proven by our study). In the case of the groups without e-negotiation, the discussion process is, by contrast, on the whole more diffuse – it is not clear whether objections are of a fundamental nature or whether one can be in agreement with the concept in spite of this. From the qualitative analyses it also becomes clear that the investigated groups with e-negotiation achieved a greater divergence in the collection of ideas and on the whole have more controversial discussions. Whether this, as presented in assumption 4, leads to a more intensive discussion on the group concept and is thus more similar to the descriptions of the group results than in groups without e-negotiation cannot be confirmed: groups without negotiation also manage to secure that their participants receive others' contributions and thus have the group results present.

On the whole, the intervention strategy "suggesting the use of an e-negotiation tool" is not sufficient to effectively promote a convergent discussion within asynchronous collaboration of a group's problem-solving processes. Our empirical investigation reveals that a positive effect may be achieved but cannot be guaranteed. We cannot clearly work out why some of the students used e-negotiation more intensively than others – a further empirical exploration may be needed to understand the factors which influence this usage behavior. We suppose that the effect of e-negotiation can be improved if the students are asked to plan in advance under which conditions e-negotiation is started and how it should be conducted (Carell et al., 2005). Additionally, the usage of e-negotiation may be more intensive if positive examples of intertwining discussions with e-negotiation are explained to them or if the participants already have repeated experience with using e-negotiation. Furthermore it can be assumed that the support of the convergent phase of an asynchronous discourse with e-negotiation is more important if a larger group is involved.

If e-negotiation is employed intensively, then it can be used in particular to make those ideas which are not compatible with others transparent to all group members. Following our understanding, the use of the tool offers advantages especially in creative problem-solving processes: in the case of dissent, creative solutions arise through critical discussion with conflicting opinions.

The results which we have achieved are of an exploratory nature. This is partly due to the quasi-experimental design of our study: a field study in which groups asynchronously work together over a longer period of time are subject to many uncontrollable factors. The biggest problem is the lack of control over the motivation for regular participation during the timeframe of the experiment. This was also a problem in our study. Despite these limitations we believe that the method of conducting experiments with e-negotiation proposed here is helpful when analyzing its effect on group discussion with respect to the degree of convergence, of the invested effort to overcome dissents, and of exploiting the opportunity of diverging ideas to achieve new insights.

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Argumentation Scheme and Shared Online Diagramming in Case-Based Collaborative Learning

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Abstract: Argumentation schemes describe patterns of reasoning in discourse. We report an investigation into whether the argumentation scheme known as 'inference to the best explanation' (IBE) captures the argumentation found in collaborative case-based learning. We examine the dialogue of three students working in an online learning environment as they attempt to explain the verdict in a legal case of medical negligence; the IDE scheme is clearly visible in the dialogue. We also report the exploratory development of shared argument diagramming tools that allow learners to draw their explanations while they discuss them. The tools passively reinforce the IBE argumentation scheme. Evaluation of the tools provided the clearest evidence to date that learners are able to integrate their shared online argument diagramming with their computer-mediated dialogue.

Argumentation schemes and case-based collaborative learning

Case-based learning is arguably the archetypal praxis for computer supported collaborative learning. Cases are representations of complex situations that call for explanation, analysis or resolution. The set of facts describing a situation will often be loosely structured, incomplete, and of varying reliability; several alternative explanations or solutions are usually possible. The case material discussed in this paper has all of these characteristics. It is an account of a law suit against a physician accused of negligence; a group of students struggles to explain the reasons for the judge's verdict in the case as part of their learning about medical law in professional practice. This making sense collectively of the facts of the case is characteristic of case based collaborative learning, and is increasingly regarded as a programmatic description of CSCL (Stahl, Koschmann & Suthers, 2006)

Learning through collaborative inquiry and explanation is an essentially inter-subjective phenomenon arising in the interactions between learners (Suthers, 2005; Suthers, Medina, Vatrapu, Dwyer, 2007). We should then regard the group of learners as a single cognitive system jointly constructing an explanation that resides in the semantic core of their discourse. More accurately, they may develop several competing explanations or converge progressively on a single explanation. Through their discussion, learners fit the facts within a structure that provides the relationships between those facts and abstracts their central meaning, rendering directly the explanation for the case (Tscholl and Dowell, 2008a). Individual learners possess distinct domain knowledge that is modified differentially by the collaborative development of explanations (Tscholl and Dowell, 2008b).

Critical argumentation is an analytical prism through which to view this process of meaning making in case-based collaborative learning. Its focus is the set of propositions in a discourse as a representation of the reasoning of the participants. It typically applies to dialectical situations where alternative conclusions are possible, but it is not limited to adversarial dialogues or disagreements. Occasionally, research is reported that finds that some particular dialogue or other contained few arguments, as indexed by the challenge or rebuttal moves it contains. However this is to use a lay notion of argument, rather than the sense of arguments and argumentation that we are concerned with here. Both the content of reasoning dialogues, and the rhetorical forms of those dialogues are the concern in critical argumentation.

People are adept at discourse as a process and no less so in a collaborative learning situation. They challenge and concede appropriately taking account of the structure of the discourse, turn taking, and previous contributions (Kuhn, Shaw & Felton, 1997; Resnick et al 1993). When their communication is computer mediated and textual, those skills are arguably even more vital to sustaining a dialogue. But in contrast with their discursive skills, the arguments learners construct, particularly when using evidence, can be relatively inadequate (Schwarz & Glassner, 2003). Those arguments may rely on non-justified beliefs rather than articulated reasons or theory, they often consist of detached reasons and may give no recognition of alternatives or rebuttal of counter-arguments (Kuhn, 1991). People frequently accept the plausibility of explanations without paying sufficient attention to their consistency with the available evidence (Brem & Rips, 2000; Weinberger et al, 2006). These observations about the weakness of reasoning with evidence apply to both everyday and expert domains, as studies of jurors' reasoning (Carlson & Russo, 2001) have clearly shown.

Critical argumentation attempts to understand the form and success of argumentation in discourse. It defines a typology of discourse types by relating them to the purposes of the discourse, the knowledge that the participants possess and come to possess in the discourse, and the methods they use. At a lower grain of analysis, critical argumentation concerns the form of arguments within distinct episodes in a discourse. It makes the important assumption that discourse contains stereotypical forms of reasoning or argumentation schemes. Argumentation schemes describe how discourse advances from one set of propositions to another, analogous to the advance from premises to conclusions in formal logic. They characterize the kinds of arguments typical of everyday conversation, arguments that subsequently can be overturned but that nevertheless provide useful heuristics for advancing understanding, particularly when information may be uncertain, unreliable or incomplete.

Many common kinds of argumentation schemes have been described; some 25 schemes are discussed in (Walton, 1996). For example, one of the most frequently cited schemes describes how expert opinion is incorporated into an argument: if a known expert asserts that some statement in their field of expertise is correct, then that statement should be regarded as correct. Argumentation schemes are useful for recognizing kinds of arguments, for recognizing the parts of arguments that are missing – such as the premises that people leave implicit, and they offer a basis for evaluating arguments. They have also been used for structuring interactions in multi-agent systems in artificial intelligence (Reed & Walton, 2005). Associated with each kind of argumentation scheme is a set of critical questions to test arguments corresponding with the scheme. For example, one of the critical questions attached to the expert opinion scheme concerns consistency: do other experts agree that the statement is correct?

We can therefore speculate that case based collaborative learning is also associated with a particular argumentation scheme, and a strong candidate for it is 'inference to the best explanation' (IBE). This scheme applies to situations where an explanation needs to be formed and where alternative explanations are possible. IBE embodies a kind of reasoning that is abductive (Walton, 2005), sometimes also called retroductive, concerned with finding the most probable explanation for some observed event or object, in terms of the preceding conditions that caused it. Josephson and Josephson (1996) argued that much reasoning in ordinary life, and in science, medicine and law is of this kind; they contemplate whether abduction and planning are the primary functions of cognition.

Abductive reasoning, in contrast with formal deductive reasoning, is intrinsically creative, transforming partial knowledge into more complete and general knowledge. That knowledge must be tentative, rather than certain, given that it involves reasoning from consequent to antecedent. Peirce described abductive reasoning as "the only kind of reasoning which supplies new ideas, the only kind which is, in this sense, synthetic" (Peirce, 1997). Abductive reasoning therefore holds considerable promise as an account of how learning arises from explanation and problem solving. Abductive reasoning gets its name from the way in which explanations are lead by the data. Typically, an observation is made that is unexpected or requires explaining for some other reason; we recognize a hypothesis that explains the observation better than any other so we tentatively adopt it as our explanation.

Walton emphasizes the discursive context of IBE where explanation is driven by the need to find answers to successive questions:

> " The best explanation is one that increases the understanding of a questioner as that individual moves forward through a search process. Of course, what increases understanding depends on the nature of the investigation... An abductive argument that is put forward by a proponent and meets the requirements for the scheme is to be evaluated in a given case with respect to how a respondent's critical questions are answered in a dialogue" (Walton, 2005, p. 206).

IBE should then be regarded as a process as much as a conclusion and at a larger scale than that of individual inferences. As a process on a larger scale, the IBE argumentation scheme describes the dialogue's lifecycle, extending from the dialogue setting, and formation of explanation attempts, through to the evaluation of explanations, and dialogue closure (Walton, 2005). A set of critical questions is associated with the evaluation phase: How adequate is the explanation relative to the alternatives? Have all the alternatives been found? How adequate is the explanation in itself for accounting for the given facts? How reliable are those facts?

To examine our assumption that IBE is the default argumentation scheme for case based collaborative reasoning, we will examine the dialogue taken from such a learning situation created in our research labs.

An observation of collaborative learning through explaining a case of medical negligence

We developed a case-based learning activity in medical law for undergraduate students taking a taught module on professional issues for clinicians. The setting for this learning activity was a collaborative learning environment constructed for the purpose. The environment provided shared access to a library of case materials, a synchronous chat system, and a shared note taking area. The students had already attended a lecture on the law of medical negligence and the learning experience we designed for our study substituted for the planned class work that would have involved a similar face-to-face discussion of cases. The learning experience we designed was focused on a case in which a general practitioner had been accused of negligence that it was claimed resulted in a patient suffering a stroke. We adapted the case for our purposes (Figure 1) from (Goldberg, 2000) to target the key issues of negligence: (i) whether the doctor's actions breached their duty of care to the patient, and (ii) whether actual harm was caused by a breach of duty of care. The relationship between these issues is potentially complex, and different qualities and forms of causation are possible. It is possible, for example, for a person to breach their duty of care, and therefore to be negligent, but for them not to be found liable for some harm that occurs because there were more significant factors involved more directly in causing the harm, because the harm was likely to have occurred regardless of the doctor's actions, etc. Hence the job of a court of law is to decide whether a person has been the victim of a negligent action and deserves compensation; disciplining a professional who has been negligent is the job of employers and professional bodies.

A 22-year old asian woman presented herself 3 times within a year at her General Practitioner's practice, with the intention of starting contraception before her marriage. She was to be married on 30th of November and was eager to start the contraception. She was warned that there were health risks associated with contraceptive pills. On the third visit, on 11th of October, her blood pressure (BP) 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' - anxiety caused by being in a doctor's presence which can, however, be indicative of a general tendency to hypertension. The next day she started the pill. She claims that within 3 weeks she returned to the GP complaining about headaches and feeling generally ill. She says the GP prescribed a medication for the headache. The GP claims this meeting did not take place and records of any meetings that occurred during this period were no longer available. A week later, the plaintiff was admitted to hospital suffering from numbness and difficulty in walking. Her blood pressure was read several times and was variously found to be at 170/110, 110/60 and 140/110. She was diagnosed as having suffered a stroke.

Note: the statistical evidence does not link taking contraceptives with stroke, over the population as a whole.

Figure 1. Description of the Vadera vs Shaw case

A group of three undergraduate medical students participated in this case-based learning experience. The students were presented with the description of the 'Vadera vs Shaw' case and were asked to explain the judge's verdict of 'negligent but not liable'. The students approach this task by giving their opinion of the doctor's negligence; they don't refer directly to the judge at all. An extract from their dialogue is reproduced in Figure 2 and includes the timestamp of each contribution. The order of a small number of contributions (those where the {timestamp} is enclosed in curly brackets) has been changed to make clearer what appears to be the intended sequence of exchanges, disrupted by time-ordered, post-once chat system.

Evidence for the IBE argumentation scheme in the dialogue

The argumentation of this group has the characteristics of both inquiry and persuasion (Dowell and Asgari-Targhi, 2008). But can the IBE argumentation scheme be recognized in the dialogue as a structure encompassing the contributions of the three learners and characterising the movement in the dialogue?

The students can be seen to move from one tentative view to another as they try to make sense of the case in relation to their understanding of the law of medical negligence. The first hypothesis they advance suggests that the general practitioner was careless but not negligent (14:23:45), considering the fact that the GP ignored the unusually high blood pressure reading. When additional facts are then considered this hypothesis becomes less sustainable, for example, the new fact introduced by the students themselves that the normal protocol would have been to take additional readings of blood pressure. There is now a tentative and somewhat tacit agreement that the GP was negligent (14:26:41). Up to this point the learners were focused on whether or not the doctor's actions were negligent, or whether they were only careless (a careless act will not necessarily be negligent). The dialogue then considers the additional hypothesis about "the not liable part" of the verdict (14:27:35). The first fact selected in relation to this hypothesis concerns the disputed consultation at which the GP is alleged to have ignored contra-indications to the prescription. David claims that this fact alone should decide the GP's liability. Gemma finally suggests a new hypothesis – that the case turns on what would have happened if the GP had not made the original prescription. This is a clear rejection of David's hypothesis and decisively re-frames the issue of the causal relationship between the doctor's actions and the actual harm suffered by the patient, which precisely applies the concept of liability. The students then look for other facts to confirm this counter-factual hypothesis and in doing so incorrectly interpret the statistical evidence: within the sub-population of hypertensives there is likely to be a significant correlation between strokes and the contraceptive pill which would then sanction the opposite hypothesis - that the GP was liable.

14:23:40 Gemma: What do u think about it david?

14:23:45 David: maybe the GP was a bit naive with teh white coat business

14:23:56 David: i mean 150/100?

14:24:05 Gemma: so u would think that she is liable?

14:24:28 David: i would tend to say no

14:24:39 David: but I am evidently wrong here

14:24:55 Gemma: i don't think I'm understanding u?

14:25:14 Gemma: which part of the verdict would u tend to disagree with?

14:25:35 David: well, i think the GP was maybe a little naive to say that such a high BP was white coat hypertension

{14:25:55} Gemma : Yep i think i could agree with u there...

14:25:46 David: but i think it was a fair diagnosis

14:26:11 Gemma: so u think she was right in prescribing the pill anyway?

14:26:18 Hywel: shouldn't he have repeated the test again at another time

14:26:21 David: Potentially

14:26:28 Gemma: Yeh thats what i though

14:26:37: David: maybe she would have been better off taking repeated BP's, maybe at home?

{14:26:51}: David: somewhere where the element of the doctors presence was reduced

14:26:41 Hywel: so he was negligent- he behaved irresponsibly

14:26:59 David: Or did he?

{14:26:40 Gemma: And we don't know what kind of history the GP took

14:27:08 David: True

14:27:12 Hywel: i agree

14:27:35 Hywel: what about the not libale part?

14:27:42 David: I think that the crux here is whether the second meeting took place

14:28:01 Gemma: Yeh

{14:28:11} David: if it did, and the GP fobbed her off, then definate case for negligance, not having followed up the symptoms etc.

{14:28:36} David: but, if not then the GP wasnt to know about any adverse affects experienced

14:28:08: Hywel: what responsibility does the doctor have for keeping the records safe?

14:28:30 Gemma: yeh what about at the pharmacy, wouldn't there be a record of the prescription there?

14:29:26 Gemma: really the question is, would she have suffered the stroke if she hadn't been on the pill?

{14:29:33} David: Indeed

{14:29:41} Hywel: apparently not- statistically anyway

…….

14:31:21 David: so are we suggesting that the GP was not guilty of breach of duty?

14:31:24 Hywel: so if he took the same action as any other doctor would have (which the facts show that he did) he is not liable

14:31:40 Gemma: i say that because of the lack of statistical evidence linking the pill with stroke that the verdict is justified

14:31:40 David: Agreed

14:31:48 Hywel: Agreed

Figure 2. CMC group dialogue extract

In the students' dialogue the four critical questions appear implicitly: alternative explanations for different conclusions about Dr Shaw's negligence and liability are advanced and compared; each explanation is assessed to at least some degree against the case facts. The reliability of the facts is considered certainly in terms of their completeness. The students definitively conclude that the GP was not liable, although they identify just one fact as relevant to this hypothesis and they only identify part of the explanation connecting the relevant facts to this hypothesis.

The students then have grasped the abstract distinction between negligence and liability but their use of it within the Vadera case is weak. David asserts that the key issue in deciding the GP's liability was whether Dr Shaw had ignored contra-indications to the prescription at a follow-on consultation. David appears to make several false assumptions here: that the GP could not be negligent for the original prescription; that negligence refers to acts of omission and not of commission; and that liability can be decided by reference to the doctor's actions without reference to whether those actions caused harm. Gemma then moves the discussion on to establish the counter-factual argument that will decide the matter. David acknowledges immediately the correctness of Gemma's argument as the central issue in deciding the GP's liability and abandons his own argument. David is learning to operationalise his concept of liability through the interaction.

This acquisition of new knowledge about medical negligence appears to be shaped by the IBE argumentation scheme. A tentative hypothesis is abandoned as new facts are considered, and a new hypothesis is tentatively accepted. As one hypothesis succeeds another, the conceptual differences underlying those hypotheses are exposed to each learner, modifying the knowledge each possesses about this domain (Tscholl & Dowell, 2008a). The naïve concept of 'being to blame' comes to be replaced by the distinct concepts of 'being negligent' and 'being liable'. However the students' ability to interpret the concepts for the particular facts of the Vadera case remains weak.

The IBE scheme characterizes the argumentation of the three students and is useful in interpreting the learning outcomes of the dialogue. Discussion of the Vadera case by a different group, and that groups' discussion of a different case of medical negligence, are examined in Tscholl & Dowell (2008b); again the dialogues can be seen to exhibit the IBE argumentation scheme which may well be characteristic of case-based collaborative learning. We now report the exploratory development of a collaborative case-based learning environment that supported shared argument diagramming with prompting of the IBE argumentation scheme.

Online collaborative argument diagramming

Graphical knowledge mapping tools are a common feature of learning environments designed for knowledge building in general and inquiry and explanation construction in particular. The list of celebrated exemplar systems includes Belvedere, CSILE, and SenseMaker (Suthers, 2003). These systems exploit a limited variety of representations, such as block and arrow graphs and structured lists for recording and analysing observations, hypotheses, backgrounder sources and evidential relations. These representations are accepted as encouraging more thorough inquiry, extended reflection, and more lucid reasoning. The learning value of knowledge mapping tools has been repeatedly demonstrated (see Kirschner et al, 2003); learners using the *CSILE* system were reported to "greatly surpass students in ordinary classrooms on measures of depth of learning and reflection, awareness of what they have learned or need to learn, and understanding of learning itself" (Scardamalia and Bereiter, 1994).

Collaborative argument diagramming provides one of the most intriguing and challenging prospects for computer supported collaborative learning environments. Such systems are those that enable a group of learners, each with their own interface, to collaboratively draw their reasoning during their discussion using synchronous groupware capabilities. Belvedere is amongst the best known of argument diagramming systems and has been examined in an online configuration, taking the original single user application program with graphing tools and source document browser/reader and augmenting them with a simple chat facility for synchronous text-based communication (Suthers 2003). Evaluations of the system with pairs of learners were comparative with the original face-to-face variant and focused on the influence of the argument graphs on the effectiveness of the collaboration.

Suther's studies provided unequivocal evidence that the argument diagrams play a greater role in the online collaboration condition; the online learners engaged in significantly more drawing activity and significantly less verbal communication activity. The greater focus on the diagram produced an increased presence in the dialogue of concepts that the software enforced, specifically on the relationships between individual facts and the categorization of statements as evidence or hypotheses. As the graph became a greater focus of the interactions between learners, new ideas were introduced directly into the diagram without first being shared verbally (an effect that could alternatively be interpreted as a breaking down of the collaboration). Suthers describes the chat transcripts as containing many examples of poorly coordinated activity, and in particular, disconnects between the activity in the workspace and the verbal activity in the chat.

A number of other efforts to assess online collaborative argument diagramming have been reported. A comparison of the online Belvedere system and the generic group meeting/authoring environment NetMeeting (available with earlier versions of Microsoft Windows) reported that the Belvedere dialogues were more conceptually oriented, though the results were confounded by the learners' difficulty in understanding the learning content (Veerman et al. 1999). Other studies with shared argument diagramming tools and synchronous communication facilities have reported that learners experienced difficulty with using the argument diagramming tools in combination with maintaining a dialogue; a comparison group working with the chat alone produced more successful arguments and achieved better learning outcomes (Baker, 2003; Baker et al.

2003). Other recent reports of online collaborative argument diagramming have also described a system where a synchronous chat facility was provided separately from the argument diagramming tool (Munneke et al. 2007). The students were asked to debate an issue of ethics in relation to genetic technology and a comparison was made of the use of the shared argument diagramming system with a group text editor for composing summaries of the debate. The data appear to show that the diagrams supported a more satisfactory analysis but the dialogue between the students showed no benefit of the diagram.

There is in most of this work a consistent absence of a strong beneficial effect of the argument diagramming, with the possible exception of some of the effects found by Suthers. The absence of a stronger effect is puzzling and seems likely to be confounded by interface design factors as much as by collaboration or learning process factors. A particular feature of all the systems is the independence of the drawing and 'talking' facilities in the interfaces, which is experienced as a lack of integration by the learners: simply, they struggle to maintain a dialogue with the chat tool and managing a collaborative drawing activity in parallel only serves to make this harder.

What is needed then is a better integration of argument diagramming and verbal discourse. It is at this point that we return to the question of argumentation schemes. If, as we proposed earlier, there is a characteristic argumentation scheme for collaborative case-based learning, then that scheme characterizes both the dialogues and the contents of the argument diagrams. If this scheme can be introduced into the user interface then it has the potential as a vehicle for integrating the chat and the drawing tool. The Araucaria argument diagramming tool (Reed and Rowe, 2004) is an exemplar of how argumentation schemes may be used to support users in building argument diagrams, although it is neither a collaborative online tool, nor is it designed or used for learning. It is possible then that use of specific argumentation schemes could be reinforced in an online collaborative argument diagramming system to encourage a better integration of discussion with argument diagramming. We now describe our exploratory build of such a system in which the IBE argumentation scheme is reinforced.

Reinforcement of the IBE argumentation scheme in collaborative argument diagramming online

The COALA system (Cooperative Argumentation and Learning application) (COALA is available freely via http://coala.gladisch.org/) provides a shared diagramming tool, a chat facility for synchronous communication and a browsable library of case materials (Dowell and Gladisch, 2007). The argument diagramming tool uses a notation similar to Belvedere consisting of two node types. Data nodes contain facts and given information of the learning material or external sources, hypothesis nodes hold assumptions or conclusions that have been made by the users. The nodes can be linked to each other with different types of connections. These can either support or refute arguments. Furthermore, these connections can be annotated by the users to show specific criteria defining the connection. This typing of links is similar to the evaluation modifiers of Araucaria (Reed and Rowe, 2004), but allows for a more flexible arrangement of arguments in the diagramming area, since all nodes can be arranged freely and a single node can support and refute multiple nodes at once.

The diagram can only be modified by one user at a time and the annotator role can be requested and passed by and to any user. The annotator chooses how often to re-fresh their drawing to the rest of the group using a synchronise function, hence their drawing activity is not visible second by second by the other learners. COALA provides cut and paste from the case library and chat window into the contents of the diagram, to place quotations directly into the nodes of the diagram. Nodes can be flexibly re-positioned in the diagram and their links automatically re-drawn.

The screen shot of COALA in Figure 3 shows the case library, chat window containing the discussion between the users, and the argument diagram which is partially complete. The case material shown is again the Vadera vs Shaw case given to the group in the first study who used the simple online collaborative learning environment. The argument diagram consists of uniquely numbered data nodes (D) and hypothesis nodes (H) linked by support relationships (single arrowhead) or refutation relationships (double-opposed arrowhead, the bold arrow indicating direction).

COALA attempts to integrate the diagramming and discussion activities through reinforcement of the IBE argumentation scheme. The reinforcement is provided by two features: the scheme checker, and the question asker, both contained in the scheme tool palette (shown in Figure 4). The palette is usually hidden from view and the user can make it visible using the controls in the window bar. The question asker reminds the learners of the critical questions that need to be asked of any argument corresponding with the IBE scheme. There are 4 such questions and the question asker feature allows learners to select one question and quote it directly in the chat system where it can be modified before sending. The scheme checker provides limited feedback on the conformance of the diagram syntactically with then IBE argumentation scheme, for example it advises users to consider additional hypotheses if appropriate.

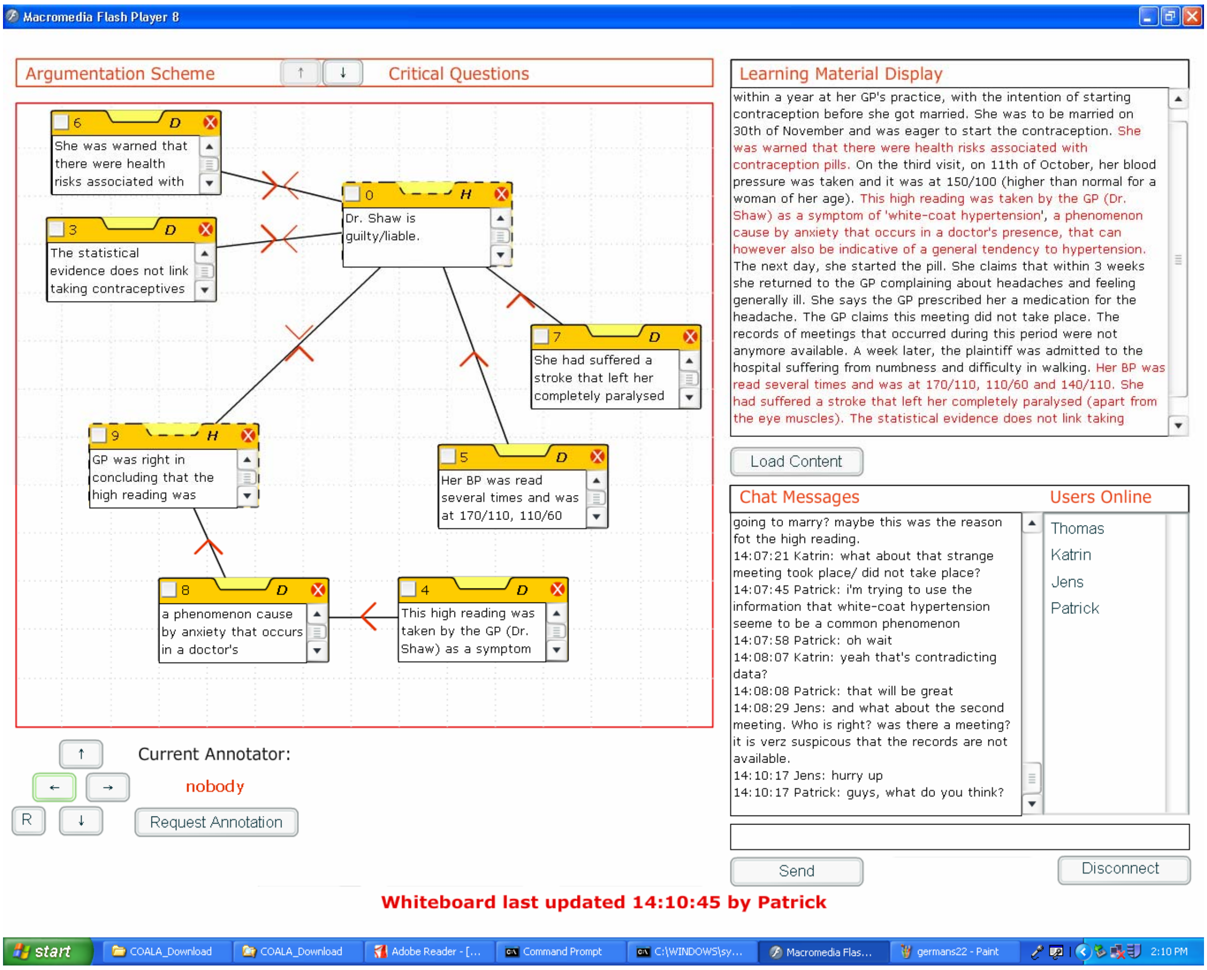

Figure 3. The COALA user interface

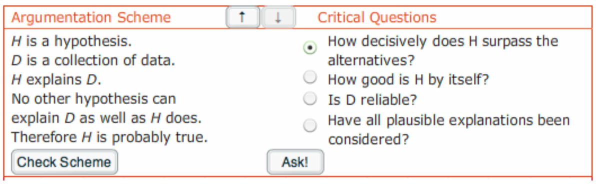

Figure 4. The argumentation scheme tool

In an evaluation of COALA with 4 groups of 3 users, a good level of consistency between the dialogues and diagrams was found (Dowell and Gladisch, 2007). The number of hypotheses introduced into the dialogues was consistent with the number of hypotheses appearing in the diagrams; similarly, the number of facts considered in the dialogues and the number appearing in the diagrams was also consistent. In post-session questionnaires, the learners indicated that the diagrams and dialogues were well integrated: the diagrams were broadly seen to be a fair or good representation of what had been discussed; the learners felt that with more practice with the tools they could produce even better diagrams. These results are in striking contrast to the reports of fracturing between dialogue and diagramming with previous online collaborative diagramming (Baker, Quignard et al. 2003; Suthers 2003).

However the results cannot be attributed to the reinforcement of the argumentation scheme tool. The learners in the evaluation (Dowell and Gladisch, 2007) made no explicit use of the tool for quoting the critical questions to the chat system, and the questions were not systematically visible in the dialogues either. In their questionnaire responses the users made clear that the critical questions were not useful. Three of the groups used the diagram checking tool to check their completed diagrams, although this did not prompt further modification of the diagrams.

The better integration of dialogue and diagram found in our study is most likely due to the direct manipulation features of the user interface, in particular, the facility for cutting and pasting text from the chat window and the case materials window into the diagram; this was well used by the learners and clearly helped them to integrate their discussion and diagramming. Simply making the system easier to use allowed the learners to devote more attention to the discussion and the task. Making the process of constructing the diagrams easier is unlikely to result in less thoughtful content in the diagrams, since the diagrams are created collectively. The integration of diagramming and discussion may have been affected by our choice of learning domain; medical negligence cases may be more amenable to diagramming than the learning cases given to learners in other studies that include pathogenetic explanations and ethical dilemmas.

The argumentation scheme tool was discretionary and limited, offering advice only to those users who sought it, and it may be that with re-design the tool would be better used. But we can also conjecture that a more active deployment of the argumentation scheme into the diagramming tool is needed to make the reinforcement felt. Suthers found that the presence of the argument diagramming encouraged his learners to refer to the concepts of the argument diagram representation, such as the relationships between the different pieces of evidence. A graphical representation of the argumentation scheme used as a framework or template in the argument diagramming tool would be likely to also encourage dialogue about the elements of the scheme, such as the adequacy of alternative hypotheses.

The development of COALA demonstrated convincingly that groups of online learners can diagram their arguments during collaborative case-based learning. The prior studies have elicited the argumentation scheme that characterizes such discussions. These findings are the correct basis on which to continue to explore ways of explicitly and actively reinforcing the argumentation scheme to facilitate argumentation in online collaborative learning environments.

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Arguing on the Computer in Scientific and Non-Scientific Domains

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Abstract: A method is employed to promote development of argumentation skills utilizing instant-messaging software as the medium of discourse. A major question investigated is transfer of argumentation skills across content domains. Forty sixth graders engaged in electronic discourse on a controversial topic, for half dinosaur extinction (the science topic) and for the other half homeschooling (the social topic). Participants collaborated with a same-side peer in arguing against successive pairs of peers on the opposing side of an issue; in addition they engaged in some reflective activities. Another 18 sixth graders served in a control condition. Although transfer occurred in both directions, science condition participants exhibited transfer of skills to the social topic to a greater extent than did social condition participants to the science topic. Results show the transfer of developing skills but also suggest the importance as well as feasibility of fostering argument skills in physical as well as social science domains.

Introduction

Argumentation has by now been recognized as central to science and to science education (Kuhn, 1993; Lehrer, Schauble, & Petrosino, 2001). Studies that have undertaken explicit teaching of argument skills in a scientific context have shown mixed results (Mercer & Littleton, 2007; Osborne, Erduran, & Simon, 2004; Zohar & Nemet, 2002), specifically with respect to the key skills of considering alternative positions and integrating evidence with claims. Zohar and Nemet's findings in particular suggest that engagement and practice in discourse itself is essential to developing such skills, as do related studies by Mason (1998) and Naylon, Keogh and Downing (2007).

The study presented here follows a line of work devoted to fostering the development of argumentation skills in early adolescents based on engagement and practice in argumentive discourse (Felton, 2004; Kuhn, Shaw & Felton, 1997; Kuhn & Udell, 2003; Kuhn et al., 2008; Udell, 2007). In addition to its status as a core component of authentic science, dialogic argument is a promising pathway for the development of individual (non-dialogic) argument skills equally critical to scientific thinking. The two are intricately connected (Billig, 1987; Kuhn, 1991; Graff, 2003), dialogic argumentation providing the "missing interlocutor" (Graff, 2003) that individual expository argument lacks. Moreover, dialogic argumentation has the advantage of building on the familiar form of everyday conversational exchange.

A particular feature of the present method is its use of instant-messaging (IM) computer software as the medium of discourse, following the successful use of this method by Kuhn, Goh, Iordanou, and Shaenfield (2008). Several studies by other researchers (Andriessen, 2006; Bell & Linn, 2000; see Clark, Stegmann, Weinberger, Menekse & Erkens for a review of studies using technology-enhanced environments to support argumentation) suggest that this medium is a fruitful one for scaffolding argumentation in science domains. In contrast to these studies, however, the present method involves no software-based scaffolding of argument construction and evaluation, beyond the instant-messaging software itself. We employed the IM method because, in contrast to the face-to-face communication, offers students an opportunity for reflection. Kuhn et al. (2008) suggest that it offers support for the development of meta-level awareness regarding the discourse. It has the benefit of providing an immediately available, permanent record of the discourse for students to reflect on, in contrast to the conditions of real-time verbal discourse, where the contents of each contribution to the dialog immediately disappear as soon as they are spoken.

A potential problem with applying in a science domain the dialogic methods used in work to foster development of argument skills is that young students are widely regarded as lacking sufficient knowledge about science topics to engage in productive debate. In the present work, we address this challenge by providing students with a constrained knowledge base (a set of "possibly relevant facts") that is equated across students (and topics) and can serve as a basis for their argumentation.

A further and critical question investigated here is that of transfer of argumentation skills across scientific and non-scientific domains. Do skills developed in the scientific domain transfer to non-scientific domains and vice versa? The research design is a straightforward one in which students are randomly assigned to one of two intervention conditions – social content or science content – and their skill level is assessed before and after the intervention in both the social and science domains. A third non-intervention (control) group is included for comparison.

Method

Participants

Participants were 58 sixth graders from a public elementary school in a middle-class suburban area in the country of Cyprus. The 40 participants in the experimental conditions consisted of the entire sixth grade and the 18 participants in the control condition were randomly chosen from the following year's sixth graders at the same school. All were 11 or 12 years of age; 35 were boys and 23 girls. Students were primarily from a middle-class population. Roughly 30% were from minority ethnic groups. Four students whose language abilities were judged by the school system as needing remediation were not included in the analysis.

Procedure

Initial assessment

Students' argument skills were assessed on the homeschool (social) topic and the dinosaur extinction (science) topic, described below, at both initial and final assessments. Control group students underwent assessments on both topics at the same times of year − with the same time interval between initial and final assessment − as the experimental group, but a year later.

The activity was introduced to the students as the NewTown project in which students were going to engage in debate regarding some issues that have come up and must be resolved in forming a new town in an unspecified location. The issues students would debate, they were told, involved the school that would be established in NewTown. One issue was whether children in NewTown must attend the town school or parents can be allowed to home school their children if they wish to (social topic). Students indicated their position by choosing among the following options: "town school", "home School" and "Undecided". The other issue concerned which of two competing explanations should be presented in science classes regarding dinosaurs' extinction (science topic). Response options for this topic were: "Dinosaurs were quickly exterminated by the collision of an asteroid with the Earth," "Dinosaurs gradually disappeared due to giant volcanic eruptions" and "Undecided."

1. Individual argument. Students' initial positions and supporting arguments regarding the social topic – home-school (HS) – and the science topic – dinosaur extinction (DE) – were assessed individually in writing. A short passage introduced the specific details of the scenario and framed the debate. They also were asked to indicate the certainty of their position on a 6-point Likert scale, with endpoints labeled "totally certain" and "totally uncertain". They were then asked for reasons supporting their position, and finally for reasons that would support the opposing view.

2. Dialogic electronic argument with opposing-view partner. For each topic, two groups of 20 students each were formed. The assignment was based on the position statement expressed on the 6-point opinion scale in the initial individual assessment, except for a few cases where it wasn't clear and we had to consider the reasons students offered for their position and the opposing position in order to make the assignment. For the DE topic, one group consisted of students who chose the volcano position (n = 19) and one undecided student; another group was formed consisting of students who were in favor of the asteroid position (n = 12) and 8 who were undecided. Similarly, for the HS topic two groups of 20 students each were formed. One group consisted of students who chose the home-school option (n = 20) and another group consisted of students who chose mandatory town-school (n = 15), or were undecided (n = 5).

The same procedure was used for the control group. Two groups of 9 students each were formed for each topic, supporting opposing positions. In this case there was an even split between the two opposing positions for both topics, i.e., equal number of students supporting each side.

Based on the contrasting groups created, pairs of students were formed consisting of one student from each group. (Pairs were different for the two topics.) The two students holding opposing views were situated on different sides of the room in a computer lab, facing away from one another and thus restricting verbal exchange or eye contact. Each such pair of students conducted a dialog on each of the two topics, implemented by instant messenger chat software (MSN) installed on each student's computer. Before pairs discussed each topic, they were reminded of the scenario and asked to engage in a serious discussion to find out where they agree and disagree; if they disagree, they were asked to figure out why and try to reach an agreement if they could. The dialogs lasted up to 20 minutes; students completed the dialog when the time elapsed or earlier if they said they had finished. The order of discussion of the science and social topics was counterbalanced across pairs. Transcripts of the dialogs were saved for analysis.

Intervention

Each student in the experimental condition was randomly assigned to one of two conditions: (a) the social condition (SOC) or (b) the science condition (SCI). The two genders were equally represented in the two conditions. The two intervention conditions were identical except for the topic (HS or DE). Students in the control condition did not participate in an intervention, but they engaged in the regular 6th grade curriculum instead.

The intervention took place over 13 40-minute sessions occurring twice per week in the students' classroom. Because of school holidays it took approximately two and one half months to be completed. The two experimental interventions took place simultaneously. Students in each intervention engaged in an extended debate on one of two topics. Students were told that they were preparing for a final "showdown" in which they would debate their topic, either HS or DE, with the group of their classmates that held the opposing view.

1. *Preparation for Supporting Reasons with Evidence.* An initial goal was to make explicit the concept of evidence as strengthening a claim. Students in each condition were divided into two teams according to their position. (Students in the SOC condition were divided into the Home-school and the Town-school teams. Students in the SCI condition were divided into the Volcanoes and the Asteroid teams). (In order to achieve an equal number of students on the two teams, undecided students were assigned to the less populated team, as described above for the initial assessment.) Students were given a list of "Some Possibly Relevant Facts". This list contained 16 facts, eight supporting each position, presented in a random order. An illustration of one from the DE fact sheet is, "Large quantities of iron and other metals that include Iridium have been found at the earth's core." An illustration of one from the HS fact sheet is, "There are published curriculum books available in bookstores that guide the teaching of subjects like math and history. They suggest what to teach the child at each point." Students were asked to review this information individually and then to decide as a team if there were any facts they wished to make use of. They discussed as a group what the implications of each of these facts were. An adult coach facilitated each group's work.

2. *Paired dialogic electronic argument with opposing-view pair*. Same-gender pairs (who shared the same view on the topic) were formed within each team. The same-side pairs remained together until the showdown preparation (see below). The pair conducted an electronic dialog with another pair on the opposite side of the room who held the opposing position on the topic. Oral instructions provided to each pair were to collaborate with their partner to determine what they wished to say and, when they reached agreement, to enter their response and send it to the opposing pair. Dialogs lasted an average of 25 minutes. At the next session, each pair debated with a different opposing pair, until each pair had debated every opposing pair – a total of five paired dialog sessions.

3. *Reflective analysis of transcripts from previous argument sessions.* After three dialog sessions had been completed, reflective analysis was introduced. In this activity, a pair analyzed the printed transcript of their immediately preceding session's dialog. Two reflection sheets were provided: the "Other Argument" and the "Own Argument" reflections. With the help of the "Other Argument reflection sheet", the pair's task was to analyze the opposing side's argument and reflect on the effectiveness of the counterargument they made and consider possible improvements to this counterargument. With the help of the "Own Argument reflection sheet", the pair's task was to review and evaluate the counterarguments made by the opposing side to their own arguments and their rebuttals to these counterarguments, and consider possible improvements to their rebuttals. When some pairs finished the reflective analysis of their own dialog's transcript, they exchanged transcripts and reflection sheets with other pairs to give and receive feedback.

4. *"Showdown" preparation session.* The students who had been working together as a pair for dialog and reflection sessions separated and were assigned to two different preparation teams. One team was assigned to be "own argument" specialists and the other "other argument" specialists. Each preparation team had an adult coach to facilitate the group process. Both groups were told that the purpose of this session was to prepare for the impending "showdown."

The "own argument" specialists were told that their task was to become familiar with the possible counterarguments the opposition might assert and to prepare rebuttals to use in the showdown. The team created a set of "own argument – counter – rebuttal" sequences that were recorded onto color-coded cards, distinguishing each part of the argument sequence. The reflection sheets completed in previous sessions were made available for this activity and further possible improvements were considered. Members of the other team were the "other argument" specialists. Their task was to review effective counterarguments to use when faced with opponents' arguments. The cards produced by this team reflected the argument sequence of "other argument − counter". Again, the reflection sheets were made available for this activity and further possible improvements were considered.

5. *"Showdown".* Students on each side of the issue were divided into two teams of five members – Team A and B. The previous "specialists" (own argument and other argument) were represented equally in Team A and B. Team A and B students on each side were seated in different rooms and the two sides communicated through instant messaging software. The dialog was projected onto a wall screen in each room. All members collaborated to come to an agreement on the text to be sent to the opposing side. One member of each team was designated as typist. During the first half of the showdown, the A teams debated. At half- time, a team change took place and the B teams continued the debate. The showdown thus consisted of a single electronic dialog between the two sides, of approximately 40 minutes duration.

6. *Judging and feedback.* The electronic dialog produced in the showdown was represented in an argument map prepared by the researchers. Different columns appeared for each team, with their contributions arranged in order of occurrence from top to bottom. All statements were represented and connected by lines to show their interrelation. Different colors were used to label statements as effective, ineffective, or neutral argumentive moves. A point system was also applied, making it possible to declare a winning team. The argument map and associated point scoring was presented to students in a session following the showdown.

Post-intervention Assessment

The final assessment was identical to the initial assessment. Students engaged in a single computer-mediated dialog with the same partners as in the initial assessment on both the HS and DE topics, as described under "Initial assessment."

Results

Coding Electronic Discourse Strategies

The analysis is based on the 116 electronic dialogs produced at initial and final assessment by students in the two experimental and one control conditions on the social and the science topics (56 dialogs per topic). Two students, one from the social experimental condition and one from the control condition, were absent during the final assessment and were excluded from the analysis. The dialogs were analyzed based on the argumentive discourse scheme used in earlier research (Felton & Kuhn, 2001; Kuhn & Udell, 2003, Felton, 2004; Udell, 2007; Kuhn et al., 2008). The coding scheme is a functional one, designed to assess the functional relation between an utterance and the opponent's immediately preceding utterance.

For coding meta-level statements – that is, statements about the dialog rather than contributions to it – the further coding scheme developed by Kuhn et al. (2008) was used. Each meta-level utterance in the discourse was segmented and categorized as reflecting one of the single-utterance meta-level operations in the coding scheme.

Thirty percent of the dialogs were randomly selected and used to calculate inter-rater reliability. Two trained coders blind to the treatment, time and identity of the students participated in segmenting and coding. Coders' percentage of agreement on coding was 89% (Cohen's Kappa = .872). After establishing inter-rater reliability, the remaining electronic dialogs were segmented and coded by one of the raters, again blind to treatment, time, and identity of students.

Argumentation skill at initial and final assessment

Assessment of the quality of argumentation is based on the coding scheme introduced earlier. Analysis focused on those categories that accounted for greater than five percent of utterances, averaged across dialogs, at both initial and final assessment. These categories are Clarify, Counter-A (Counter-Alternative, consisting of disagreement together with proposal of an alternate argument) and Counter-C (Counter- Critique, consisting of disagreement accompanied by a critique of the opponent's argument). All other categories accounted for 5% or less of utterances at the initial and/or the final assessment. Counter-C, Counter-A and Clarify are the argumentation strategies that in previous research have been found to either decrease (Clarify) or increase (the two types of Counterarguments) with practice (Felton, 2004; Kuhn and Udell, 2003; Kuhn et al., 2008), as students begin to recognize the relevance of and accord more attention to the opponent's statements. Given the differences in number of utterances across time and conditions, percentages of usage were calculated for each student, rather than frequencies. An arcsine transformation was used to normalize these proportions. To test the effect of conditions a 3 X 2 X 2 (Condition X Topic X Time), repeated-measures analysis of variance was performed, as well as a 3 X 2 (Condition X Time) repeated-measures analyses of variance for each topic separately.

Use of Counterarguments on intervention and non-intervention topic

In analyzing changes in counterargument usage across conditions, three indicators were employed. The first is the proportion of utterances that were coded as Counterarguments, including both the more accomplished Counter-C strategy – which seeks to directly weaken the force of the opponent's preceding argument –and the less accomplished Counter-A strategy – which does not directly address the opponent's preceding argument, but proposes an alternative argument. The second is the proportion of utterances that were coded as Counter-Cs, and the third is the proportion of Counterarguments that were Counter-Cs.

Overall counterarguments

An analysis of overall Counterargument usage revealed a 3-way interaction, $F(2, 53) = 11.08$, p <001; partial $\eta^2 = .295$, for Condition X Time X Topic. Overall, students at the initial assessment showed greater usage of Counterargument strategies on the social topic than the science topic (suggesting that the social topic is more facilitative of counterargument). By the end of the intervention, however, students in both experimental conditions increased their Counterargument usage, with the science condition students exhibiting equivalent achievement on both topics.

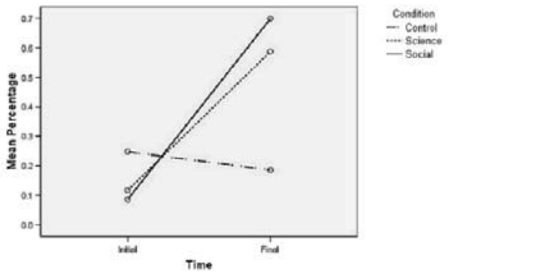

Figure 1. Percentage of utterances that were coded as overall counterargument on the social topic (HS) by condition.

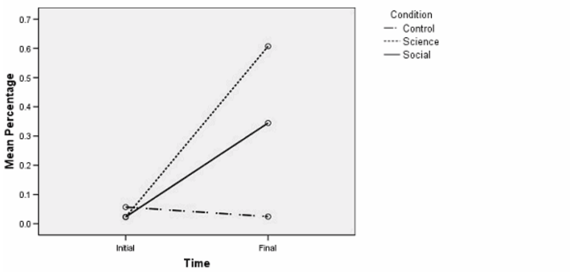

Figure 2. Percentage of utterances that were coded as overall counterargument on the science topic (DE) by condition.

A 2-way analysis on the social topic showed that there is a significant Topic X Condition interaction, $F(2, 53) = 44.581$, $p < .001$, partial $\eta^2 = .627$. As shown in Figure 1 the two experimental conditions were equally effective in raising overall Counterargument usage on the social topic, whereas the control condition was not effective, $F(2, 53) = 10.256$, $p < .001$, partial $\eta^2 = .279$. Of particular interest is the fact that students in the science condition were able to show transfer of their counterargument skill to the social topic, in fact to the same extent as that shown by students in the social condition, for whom this was their intervention topic.

A 2-way analysis for the science topic also showed a significant Topic X Condition interaction $F(2, 53) = 51.73$, $p < .001$, partial $\eta^2 = .661$. Although the two experimental conditions were effective in raising overall Counterarguments, compared with the control condition ($F(2, 53) = 36.749$, $p < .001$, partial $\eta^2 = .581$) the magnitude of their effectiveness was different, $p < .001$. As seen in Figure 2 the science condition was more effective in raising overall Counterargument usage (M = 56.1%, *SD* = 15.18) on the science topic than was the social condition (M = .92%, *SD* = 20.4). However, Bonferroni Post Hoc analysis revealed that the social condition produced significantly more Counterarguments compared to the control condition (*M* = 2.42%, *SD* = 7.39), demonstrating the ability of the social condition students to transfer their counterargument skills to the non-intervention science topic.

Counter-C

A 3 X 2 X 2 (Condition X Time X Topic) repeated-measures analysis of variance for Counter-C revealed a 3-way interaction $F(2, 53) = 4.585$, $p = .015$, partial η^2=.147. Again, at the initial assessment students showed greater usage of Counter-C on the social topic. A separate 2-way (Condition X Time) repeated-measures analysis of variance for the social topic showed a significant Time X Condition interaction $F(2, 53) = 24.808$, $p < .001$, partial $\eta^2 = .484$. The two experimental conditions were comparably effective in raising Counter-C usage, compared to the control condition $F(2, 53) = 4.073$, $p = .023$, partial $\eta^2 = .133$. As seen in Figure 3, students in the social condition increased from 7.03% (*SD* = 10.46) to 45.72% (16.42), students in the science condition increased from 9.09% (13.21) to 43.76% (15.35), whereas control participants showed no improvement.

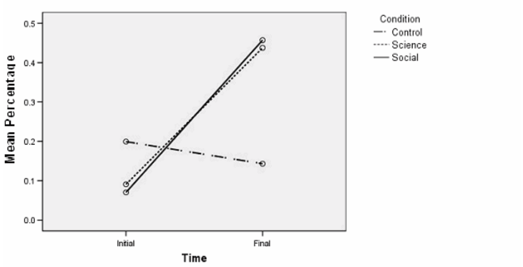

Figure 3. Percentage of utterances that were coded as counter-c on the social topic (HS) by condition.

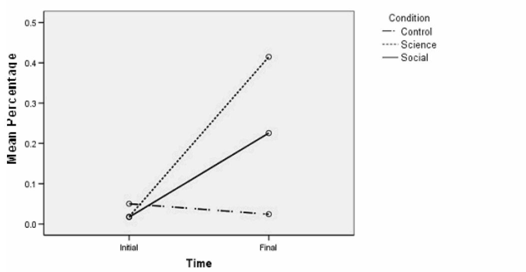

Figure 4. Percentage of utterances that were coded as counter-c on the science topic (DE) by condition.

A 2-way analysis for the science topic showed a significant Time X Condition interaction $F(2,53) = 28.027$, $p < .001$, partial $\eta^2 = .514$. As in the analysis of overall Counterarguments, only students in the experimental conditions showed an increase in Counter-C usage, $F(2, 53) = 20.176$, $p < .001$, partial η^2 =.432. However, as shown in Figure 4, the increase exhibited by students in the science condition, from 1.83% (*SD* = 4.97) to 41.48% (18.01), was greater than the one exhibited by students in the social condition, from 1.707% (5.26) to 22.56% (18.36). Students in the social condition nevertheless showed greater improvement in Counter-C usage in the science topic compared to the control group (Bonferroni Post Hoc test, $p = .019$), demonstrating their transfer of Counter-C skill to the non-intervention topic.

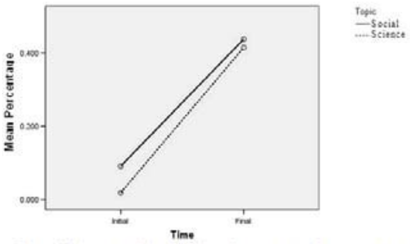

Figure 5. Science condition participants' percentage of utterances that were coded as counter-c by topic.

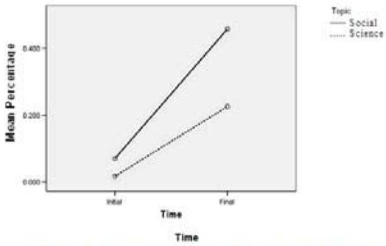

Figure 6. Social condition participants' percentage of utterances that were coded as counter-c by topic.

Students in both experimental conditions, we saw, exhibited some transfer of their gains in Counter-C usage to the non-intervention topic. However, as seen in Figures 5 and 6, only students in the science condition were able to transfer their Counter-C skills to the non-intervention topic to the same level that these skills were mastered in the intervention topic.

Individual patterns of change

In addition to analysis of group trends, of equal importance is analysis of changes at the individual level. In this analysis we examined the percentage of students who produced at least three Counterarguments or Counter-Cs. The criterion of "at least three" ensures that production of counterargument was not a random incident, but the result of significant mastery of the skill. Before examining change, we looked for evidence at the individual level to confirm the group pattern suggesting that the social topic is in general more facilitative of counterargument. Individual-level analysis further supported this finding: At initial assessment no student exhibited adequate mastery of Counter-C or Counterargument usage in the science topic, whereas 18% – 10 of 56 – produced at least 3 Counter-Cs and 29% – 16 of 56 – produced at least 3 Counterarguments on the social topic at the final assessment (Fisher's Exact Test, p < .001).

Table 4. Initial and Final Percentages (and number) of Students Who Produced at Least Three Counter-Cs and at Least Three Counterarguments by Topic and Condition

Topic	Condition	Counter-Cs Initial Assessment	Counter-Cs Final Assessment	Counterarguments Initial Assessment	Counterarguments Final Assessment
Social Topic	Social (N=19)	21% (4)	95% (18)*	21% (4)	100% (19)**
	Science (N=20)	5% (1)	90% (18)*	10% (2)	100% (20)**
	Control (N=17)	29% (5)	0% (0)	59% (10)	0% (0)***
Science Topic	Social (N=19)	0% (0)	58% (11)*	0% (0)	74% (14)**
	Science (N=20)	0% (0)	90% (18)**	0% (0)	100% (20)**
	Control (N=17)	0% (0)	0% (0)	0% (0)	0% (0)

$p = .001$, McNemar test. $^{**}p < .001$, McNemar test. *** $p < .002$, McNemar test

Turning now to change, Table 4 presents the percentages (and numbers) of students who made at least 3 Counter-Cs and Counterarguments at initial and final assessment on both the intervention and non-intervention topics. For example, as seen in Table 4, at the initial assessment none of the science condition students made at least 3 Counter-Cs on their intervention (science) topic. At the final assessment 90% – 18 of 20 – did so (a significant change, $p < .001$, McNemar test). While both experimental conditions showed increased usage of Counterargument strategies on both topics, none of the control condition students produced more than 3 Counter-Cs or counterarguments on either the social or the science topics at the final assessment.

Finally, the discrepancy between social and science condition students with respect to their ability to transfer their Counterargument skill to a different domain was still distinctive. Only about half – 11 of 19 – of the social condition students were able to produce at least 3 Counter-Cs on the science topic (transfer topic), whereas almost all – 18 of 20 – of the science condition students did so on the social topic (transfer topic) at the final assessment.

Use of Exposition (Clarify) on the intervention and non-intervention topic

The expectation of a decline in the proportion of Clarify utterances as participants devoted more attention to Counterargument, was confirmed. A 3-way analysis of variance for Clarify revealed a Time X Condition significant interaction, $F(2, 53) = 6.961$, $p = .002$, partial $\eta 2 = .208$. These results were also supported by a 2-way analysis for each topic separately. The two experimental conditions were equally effective in decreasing the proportion of utterances devoted to exposition of own position on both topics. Social condition students decreased from 30.26% (SD 18.97) to 9.40% (9.65) on the social topic and from 30.26% (18.97) to 9.40% (9.65) on the science topic. Similarly, science condition students decreased from 37.64% (SD = 21.24) to 14.75% (9.93) on the social topic and from 40.98% (21.46) to 12.96% (11.94) on the science topic. In contrast, control students showed almost no change, exhibiting 38.83% (18.29) at initial assessment and 39.79% (17.98) at the final assessment on the social topic and 44.03% (23.98) at initial assessment and 42.45% (27.27) at the final assessment on the science topic.

Use of Rebuttal on the intervention and non-intervention topic

A further important aspect of argument skill is the extent to which students are able to maintain focus and consistency in intent and execution to an extent that enables them to sustain the critique of one another's arguments. To examine this skill, we observed both the frequency of Rebuttals and the length of Rebuttal strings. Rebuttal is defined as a Counter-C immediately following a Counterargument by the opposing partner (Felton & Kuhn, 2001; Udell, 2007). When the opponent critiques one's argument, through either a Counter-A or a Counter-C, the subject rebuts the opponents' critique by taking back the force of his or her own argument. Rebuttals entail a sequence of strategies involving both partners; therefore a different form of analysis is required than that employed for the Counterargument strategies since opportunity for Rebuttal depends on the partner's production of Counterarguments. In order for students to exhibit their ability to produce Rebuttal, it is required that they are offered at least one Counterargument from their opposing partner. Because students' failure to make a Rebuttal could be due either to lack of ability or lack of opportunity, in order to exclude the latter possibility analysis of Rebuttal focused only on those students who had an opportunity to make a Rebuttal.

On the social topic, only half of the experimental condition students – 17 of 39 – had an opportunity to make a rebuttal at initial assessment and of those who had an opportunity only half of them did so – 9 of 17. A significantly higher proportion of control condition students made a Rebuttal – 13 of 14 – at initial assessment on the social topic ($a = .018$, Fisher-Irwin test). Most of the control condition students had an opportunity to make a Rebuttal and almost all of them did so. At the final assessment however, the proportion of experimental condition students who made a Rebuttal – 38 of 39 – was significantly higher than the corresponding proportion of the control condition students – 2 of 8 – ($a = .018$, Fisher-Irwin test). No significant difference was observed between the two experimental conditions on the social topic.

On the science topic, only a few students had an opportunity to make a Rebuttal at initial assessment – 11 of 57 –, across all conditions, and only a few of these actually made a Rebuttal – 3 of 11. Yet, at the final assessment the proportion of experimental condition students who produced a Rebuttal – 33 of 37 – was significantly higher than the proportion of the control condition students who did so – 0 of 3 – ($a < .001$, Fisher-Irwin test). In addition, a difference was observed in performance across the two experimental conditions. Although all of the science condition students who had an opportunity to make a Rebuttal made a Rebuttal – 20 of 20 –, not all of the social condition students who had an opportunity to make a Rebuttal did so – 13 of 17 – ($a = .036$, Fisher-Irwin test). This finding of the differential performance of the social and science condition students on the science topic is consistent with the differences observed in overall Counterargument and Counter-C usage analysis.

Finally the length of Rebuttal strings was examined. A length of 1 represents a sequence of assertion-counterargument-counterargument (Rebuttal), a length of 2 represents a sequence consisting of assertion-counterargument-counterargument (Rebuttal)-counterargument (Rebuttal). Below is an example of a successful Rebuttal chain of length 3.

Example of Rebuttal Chain (Length 3)

A: Lava spreads out everywhere. (Assertion)
B: Some dinosaurs could jump in the sea that is near to the island.
(Counter-C) A: Yes, but they will drown. [Counter-C (Rebuttal)]
B: Some dinosaurs may make it to a neighboring island. [Counter-C (Rebuttal)]

Results showed that experimental condition students who had the opportunity to make Rebuttals increased the length of Rebuttal from initial to final assessment on both topics, whereas control condition students who had Rebuttal opportunity showed no increase from initial to final assessment. In contrast, among social condition students having Rebuttal opportunity, mean length of Rebuttal increased from 2.5 to 3 on the social topic and from 1 to 2.25 on the science topic. Among the corresponding group of science condition students, length of Rebuttal increased from 1 to 2.49 on the social topic and from 0 to 2.71 on the science topic. Due to the reduced sample size however, a statistical analysis was not conducted.

Discussion

The present study shows that a collaborative computer-based activity centered on engagement, practice and reflection can promote students' argumentation skills in the scientific domain, as it can also do in the social domain. This method proved also to be successful in producing transfer of argument skills across domains in both directions – from science to social and social to science domains. However, a difference in the magnitude of transfer was observed, with only students in the science condition able to transfer their achievements in argumentation skill to the non-intervention (social) topic to the same degree that these skills were mastered in the intervention (science) topic. We begin our discussion of results with the development of argumentation skill within the domain in which students engaged and then proceed to the issue of transfer of this skill across domains.

Development of Argument Skills Within a Domain

The intervention proved effective in developing students' argument skills in the domain in which it was carried out. Students exhibited an increased frequency of usage of advanced (Counterargument and Rebuttal) argument strategies and decreased frequency of less advanced (Exposition) strategies within the context of their intervention topic. Although initially only a few students exhibited the Counter-C strategy, by the end of the intervention all did so. Regarding the advanced strategy of Rebuttal, of the students who had an opportunity to make a Rebuttal only a few made a Rebuttal at initial assessment, whereas all did so in the science condition and all but one in the social condition at the final assessment. In addition, students exhibited increased proportion of usage of the more advanced Counter-C strategy, in contrast to the less advanced Counter-A strategy. Social condition students doubled the percentage of Counterarguments that were Counter-C in the social domain and science condition students' percentage was four times greater at the final compared to initial assessment in the science domain.

Our findings in the social domain are consistent with findings of previous cross-sectional (Felton & Kuhn, 2001) and experimental studies of developing argumentation skills in the social domain, using similar methods (Kuhn & Udell, 2003; Felton, 2004; Kuhn et al., 2008), as well as methods based on similar theoretical principles (Anderson et al., 2001, Nussbaum, 2005; Reznitskaya et al., 2001). The major contribution of the present findings is in documenting the effectiveness of the development of argumentation skills in the science domain. Although the central role of argument to science and science education has been widely endorsed by science educators (Erduran, Simon & Osborne, 2004; Kelly, Regev & Prothero, 2008; Driver, Newton & Osborne, 2000; Lehrer, Schauble & Petrosino, 2001), developing these skills in science students has proven challenging (Osborne, Erduran, & Simon, 2004) and understanding of mechanisms of development is at best incomplete. Our findings show that forms of engagement and practice that have been shown to support development of argumentation skills in the social domain can also support this development in the science domain. This result establishes that students' limited argument skills in the science domain reported in several studies (Solomon, 1992; Driver et al., 2000) are not due to constraints imposed by the nature of the science domain itself.

Control condition performance, showing no improvement in either the social or the science domain, establishes that the limited opportunities offered by the regular curriculum to practice argumentation or merely the passage of time are not adequate to advance students' argumentation skills. Also it should be noted that control condition students' performance at initial assessment was comparable to that of students in the experimental condition, and a few control condition students even showed a slight advantage over experimental condition students at the outset, making the study's findings even stronger. The decline in performance of control condition students from initial to final assessment suggests the critical role of students' interest and motivation in developing the kinds of cognitive skills examined here. For control condition students, final assessment was a mere repetition of the activity they engaged in two months earlier, and they did not see any value in repeating it. Among the experimental condition students, in contrast, the goal-based nature of the activities proved effective in maintaining their interest and involvement throughout the intervention.

Development of Argument Skills Across Domains

Regarding the critical question of the transfer of argumentation skills across domains, our results show that transfer does occur across scientific and social domains. Post-intervention performance on the non- intervention topic was superior to control-condition performance in both conditions. How was this transfer achieved? One mechanism we propose to contribute to the transfer of argument skills across domains is the development of meta-level awareness and understanding of the objectives of argument and in particular of the relevance of the other person's position. It is possible that this developing meta-level understanding supports the execution of argument skills at the procedural level across domains of application. In addition, the improvements observed might also be supported by epistemological beliefs and their associated dispositions – needing to see the point of argument to invest the effort it entails.

Such asymmetry in our main results is arguably the most notable of our findings. Students in the science condition were able to transfer their counterargument skills to the non-intervention topic to the same level that these skills were mastered in the intervention topic. In particular, the science condition did the better job of increasing Rebuttal on the science topic, while the two conditions were equally effective in increasing Rebuttal and Counter-Cs on the social topic.

One explanation for the condition difference we observed is that the social topic is more facilitative of counterargument, a difference documented at the initial assessment. Students overall exhibited greater counterargument usage on the social topic than they did on the science topic, a finding consistent with previous research (Osborne, Erduran & Simon, 2004). The encouraging message, however, that the present study carries is that argumentation skills in the science domain are amenable to development. This was true in the present study to the extent even of overcoming the initial performance difference across domains.

Finally, and perhaps most important, are the specific implications the present findings have for science education policy and practice. Direct attention to the development of argumentation skill within science domains is warranted. Argument skill in the science domain is amenable to the same development as argument skill in the social domain has been shown to be, but specific engagement and practice within the science domain is required for optimum development of such skill. The policy recommendation supported by the present findings – engagement and practice in argumentation within the context of authentic science topics – is consistent with the educational objective of fostering students' competence to assume roles in meaningful scientific discourse, rather than become merely consumers of scientific facts.

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The Effects of Task Characteristics on Online Discussion

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Abstract: A key guidance factor of computer supported collaborative learning (CSCL) is the specification of a discussion task. Aspects of the discussion task may affect the quality of group discussion for higher-order learning. This experiment investigated the effects of two aspects of discussion task on asynchronous text discussion of an online higher-education course. Groups completed discussion assignments that varied in degree of task context and outcome specification. Content analysis was used to assess conceptual conflict and level of information processing of online messages. Results indicate that conceptual conflict is associated with higher-order discussion, but differences in task context and product do not have large effects on the quantity or quality of online discussion.

Introduction and Research Overview

Wiley and Bailey (2006) describe *process loss* as the less effective performance of groups in completing some tasks. A significant body of research, however, has shown that collaborative learning groups, including online groups, can foster shared understanding, retention of learned material, and deeper processing compared to non-cooperative learning activities (Johnson & Johnson, 1994; Johnson, Maruyama, Johnson, Nelson, & Skon, 1981; Slavin, 1987, 1992; Yeager, Johnson & Johnson, 1985). Other research supports the assertion that collaborative learning can promote higher-order learning such as critical thinking (e.g., Anderson, Howe, Soden, Halliday & Lowe, 2001; Gokhale, 1995; Meyer, 2003). Such research suggests that collaborative learning groups have characteristics that result in *process gain* in comparison to other group efforts. A major focus of collaborative learning research is to identify what characteristics result in process gain and how learning can be designed to maximize such gain in addition to meeting learning goals.

Computer supported collaborative learning (CSCL) often relies on peer-to-peer discussion as the key activity supporting achievement of higher-order learning objectives. Hammond's (2005) survey of online discussion studies lists several that cite evidence of higher-order knowledge construction and learning advantages of group discussion. Efforts to improve process gain of learning by discussion include efforts to understand how aspects of discussion *task* may affect the quality of peer discussion. This study investigated how two aspects of discussion task affect asynchronous online discussion (AOD) associated with higher-order learning.

Characteristics of High-Quality Discussion for Higher-Order Learning

Models of learning by discussion, such as the Process of Controversy model of Johnson and Johnson (1979) or the Collaborative Knowledge Building model of Stahl (2000), indicate that for higher-order learning to occur, information expressed in discussion must vary (diverge) sufficiently to achieve *conceptual conflict* among students. Conceptual conflict occurs when students encounter ideas and information that do not fit with what they believe to be true (Johnson & Johnson, 1979). These models assert that collaborative learning occurs when students encounter cognitive conflicts and then engage in group processing of information to identify or produce a shared interpretation that completes the discussion task. Discussions in which ideas and assertions diverge and conflict tend to promote learning, especially higher-order learning.

In completing a group learning task, group members process shared information to identify or generate information that members agree resolves the task (i.e., information *converges* to a task solution). A group can process information by negotiation, questioning, and argumentation (Andriessen, 2006, Andriessen, Baker & Suthers, 2003; Spatariu, Hartley & Bedixen, 2004), but CSCL discussions often do not converge. Andriessen (2006) found that online discussion messages tend to be both unconnected (do not reference each other) and non-argumentative. Hewlitt (2005) found that students tend to focus only on the most recently posted messages, while older messages tend not to be reexamined or referenced. Lobry de Bruyn (2004) found low levels of analysis, synthesis, and summarizing ("convergent processes") displayed in discussion messages. Online discussions often fail to integrate diverse ideas, opinions, and suggestions into new group knowledge that indicates higher-order learning.

Peer discussion may fail to support higher-order learning because information does not sufficiently diverge to create conceptual conflict. When peer discussion does diverge sufficiently, students often do not connect the different ideas expressed and do not return to explain, summarize, or reach conclusions about issues.

Measuring Discussion Quality

Discussion divergence is beneficial if it stimulates conceptual conflict within group members (Spatariu et al., 2004), so one measure of quality of discussion for learning is the amount of conceptual conflict evident in the discussion. Such conflict, however, is insufficient for collaborative learning. Group members must also process information to identify or generate information that the group agrees resolves the discussion task. Information convergence is difficult to measure, but researchers can measure the type of information processing present in a discussion. Such processing, displayed in online text-only discussion messages, suggests whether information is diverging and converging. The type of information processing displayed in discussion messages also indicates whether higher-order learning is occurring. This study measured discussion conflict and level of information processing observed in online messages and indicators of discussion quality for learning.

Measuring Collaborative Information Processing

Several studies use content analysis to analyze the quality of online discussions or to access more detail about the collaborative learning process (De Wever, Schellens, Valcke & Van Keer, 2006; Rourke, Anderson, Garrison & Archer, 2001). Veerman, Andriessen, and Kanselaar (1999) classify "constructive activities" in messages into three categories: 1) added, explained, or evaluated; 2) summarized; 3) transformed. This scheme can be seen as an information processing approach in that constructive activities can be viewed as levels of information processing. Comparison of content analysis instruments used in CSCL studies reveals that several instruments tend to agree on only two basic classifications that are similar to the added and transformed categores of the Veeman et al. (1999) classification scheme (Jorczak, 2008).

The measurement approach adopted for this study, therefore, used two categories of information processing displayed in messages: 1) *adding/clarifying* diverse information to the discussion from knowledge sources; and 2) *generating* (creating) information new to the group (and not obtained from a source) that resolves conceptual conflict and achieves group goals. The adding/clarifying category involves processing to obtain information including judging it relevant to the discussion task and clarifying or stating the information in a way that is meaningful to all group members. The generating category requires group or individual cognitive processing involving inferring or elaborating, resulting in relevant new information that comes from neither a source outside the discussion nor any member's prior knowledge.

Following this approach, this study created a content analysis instrument by which discussion messages were placed into one of three levels of information processing: repetitive (no additional information added to the discussion), additive, and generative. The differences in additive and generative levels are consistent with the distinction between lower- and higher-order learning adopted for this study.

Measuring Conceptual Conflict

Andriessen (2006) coded messages into six categories of "dialog moves" including statements, checks, challenges, counters, acceptances, and conclusions. Three of these categories (check, challenges, and counters) display disagreement (Andriessen, 2006; Veerman et al., 1999). The amount of disagreement expressed in a discussion is related to the amount of conceptual conflict present in the discussion. Agreement and disagreement are often explicitly expressed in discussion messages. Implicit disagreement can be identified by messages that check, challenge, and counter statements of other students (Veerman et al., 1999). Only two categories of messages are defined for measuring discussion conflict in this study: 1) neutral/agreeing and 2) disagreeing.

Variables that Affect Discussion Quality

Several variables have been suggested and investigated as affecting the quality of online discussion. For example, Wiley and Bailey (2006) suggest that task coordination, group interdependence, and amount of argumentation are factors that determine if collaborative learning displays process loss or gain. Lobry de Bruyn, (2004) found that instructional interventions can improve discussion convergence. Hewitt (2005) agrees that instructor interventions can shape electronic discourse, and he lists course design, software interface design, and individual student differences as factors that affect learning by discussion. Similarly, Veerman and Veldhuis-Diermanse, (2006) suggest four categories of such factors: instructors, communication medium, students, and learning task.

Instructional *guidance* has been identified as a necessary component of any instructional design (Kirschner, Sweller & Clark, 2006), and it is rare to observe effective interaction in spontaneous unguided student discussions (King, 2007; Weinberger, Stegmann, Fischer & Mandl, 2007). Discussion tasks are a key means for instructional designers to guide discussion toward more divergence and convergence of information. To date, lacking direction from research, task specification for productive online discussion has often been inadequate. Kirschner, Beers, Boshuizen, & Gijselaers (2008) opine:

> With respect to tasks, it is too often the case that the learning tasks are not suited to collaboration….They are often too closed (i.e., there is little room in the problem space to discuss), too easy (i.e., it can more efficiently be carried out by one person than by a team), or too controlled (i.e., there is little room for learner initiative)…. (p. 404)

CSCL researchers have suggested several task characteristics that may affect discussion quality, including task *scripting*, *function,* and *goal*. Scripting can improve discussion (King, 2007). Scripting involves detailed instructions that guide student discussion and may include a template of expected student responses, such as the labeling or diagramming of the discussion (e.g., Fischer & Mandl, 2005; Suthers, 2003). Tasks can be scripted to scaffold students to adopt specific modes of interaction (e.g., argumentative). Highly-structured tasks lessen the management burden on students and let them spend more time on the task (Veerman & Veldhuis-Diermanse, 2006; De Wever, 2003). Veerman and Veldhuis-Diermanse (2006) suggest a positive correlation of task structure with knowledge construction and also found that tasks with designated student roles or perspectives (a type of structuring) resulted in more discussion.

Differences in task function are also thought to affect discussion. For example, the type of discussion task can directly affect the amount and quality of question asking and argumentation in discussion (e.g., Rose & Flowers, 2003; Wiley & Bailey, 2006). Controversial tasks can stimulate argumentation. Nussbaum (2005) found that tasks that specify different discussion goals substantially affect characteristics of student discussion. The goals "to persuade" and "to generate reasons" had the strongest effect on argumentation. The persuasion goal resulted in more conflict and debate. The goal "to explore" increased discussion divergence and resulted in more connected messages (Nussbaum, 2005).

Task Context

Naidu and Oliver (1999) are among the researchers who stress the importance of operating within a context during instruction. From a cognitive perspective, highly contextualized tasks (those providing specific and realistic details) promote the recall and sharing of student ideas and experiences, because the additional details of context stimulate students' episodic memories of events within the proposed or similar contexts. Providing details of context should serve to activate schema in long-term memory and therefore enable students to provide more information about the discussion topic. Highly-situated tasks may increase the amount and quality of discussion by increasing the introduction of new and diverse information, thereby increasing opportunities for conceptual conflict and knowledge negotiation.

Increased context of discussion tasks should make discussions more realistic which would, according to some proponents of situated learning, improve learning (e.g., Greeno, More & Smith, 1993). Theoretical models, such as social constructivism, suggest that detailed, or at least more realistic, contexts can be expected to promote learning. Social constructivist theory posits that "authentic" activities (those similar to activities encountered outside the classroom) have learning benefits such as the more realistic use of social resources and increased meaningful connections (Ormrod, 2008, p. 343). Online discussion tasks provide an opportunity to test whether increased detail of task context affects aspects of discussion associated with learning.

Task Product

One approach to the lack of discussion convergence is to specify tasks that require the creation of a final product or statement of group consensus. Wiley & Bailey (2006) point out that successful collaboration occurs when students must cooperate to achieve a goal (i.e., accomplish an interdependent task). It is likely that a specific end product or goal stimulates students to share information and to discuss and learn from the knowledge, experiences, beliefs and values of other students (Veerman & Veldhuis-Diermanse, 2006). Andriessen (2006) suggests that effective argumentative discussion requires that students share and maintain a focus on the themes and problems of the discussion task. Specification of a group product (e.g., a written statement of consensus, or creation of a product such as a slide presentation) may act to strengthen group focus on a topic. A specific task outcome may promote a merging of effort with clarity of goal that promotes the cognitive learning processes of knowledge negotiation and synthesis.

Research Questions

Theory and research about online collaborative discussion for learning lead to these assertions: 1) Of the many variables that may affect online discussion for learning, discussion task characteristics are key variables of instructional guidance affecting the level of both cooperation and conceptual conflict in online discussions. 2) Productive discussions for learning tend to first display divergence of information (stimulating conflict), and then convergence on a task resolution that may include generated (i.e., higher-order) information. A research question of interest would investigate the relationship of task variables to discussion characteristics such as conceptual conflict (a type of divergence) and type of information processing (indicative of both divergence and convergence).

This study investigated the effect of task *context* (authentic details) and *product* outcomes (written task products) on the amount of conceptual conflict and information processing present in asynchronous online discussions for learning. This study also sought to assess the relationship between conflict and the level of information processing in asynchronous online text discussions. The following hypotheses were investigated:

H_1: Discussions displaying increased conflict result in higher levels of information processing.
H_{2a} H_{2b}: Higher specification of task context (2a) or product (2b) will increase the number of messages in a discussion.
H_{3a} H_{3b}: The degree of context specification in a discussion task presented to a small online collaborative learning group will affect the amount of conceptual conflict (3a) and information processing (3b) observed in discussions.
H_{4a} H_{4b}: The degree of specification of task product presented to a collaborative learning group will affect the amount of (4a) conceptual conflict and (4b) information processing observed in discussions.

Methodology

Environment and Participants

Participants were graduate and undergraduate college students in an online semester-long survey course about educational psychology theory. The class included 30 students; female graduate students predominated, but the class included some males and undergraduates. Students were randomly assigned to one of eight discussion groups of 3-5 members. Assignments included six asynchronous text-only discussions; four were part of the experiment. Scores for online discussion were assigned to individuals based on a grading rubric designed to encourage participation. Small group discussions accounted for 30 percent of each student's final grade.

Research Procedures

Manipulated Variables

The experiment manipulated two aspects of the written description of a discussion assignment: *task context* and *task product (outcome).* Task context is the amount of detail (low/high) provided in the task description that places the task in a realistic context. Task product is the degree (low/high) to which a task outcome is specified; the high outcome condition specifies a written product.

For example, a low context and low product task specification asks: "In your group, discuss and list the basic differences and similarities between behavioral and cognitive perspectives of learning. There is no need to post anything in the whole class discussion." The high context and product condition is represented with this text:

> Imagine your group is selected to deliver an in-service teacher workshop at the beginning of the school year. The topic is 'basic differences and similarities between behavioral and cognitive perspectives on learning.' Because of the busy in-service schedule, you have been allocated 15 minutes. You should specify the context of the in-service workshop (e.g., grade level) and present information appropriate to that context. Discuss what you would include in this presentation with your small group. After group discussion, create a brief slide show of your presentation and attach it to a message in the whole class discussion.

The last sentence of this high context specification sets a *high product* condition in which a specific written product is required (a slide presentation) that must be posted online. The high and low levels of context and product resulted in four experimental conditions for this single discussion assignment.

Experimental Design

A completely randomized 2x2 factorial experimental design was implemented. The eight discussion groups were randomly placed into the four experimental conditions (two groups per condition). Each set of two groups was given an alternate version of a discussion assignment that varied the two variables of task specification. Each discussion assignment, therefore, required four variations to implement the four experimental conditions. The arrangement of two groups per condition was repeated for three additional discussion assignments and each set of two groups was rotated through all of the experimental conditions (but for different assignments addressed at different times during the semester). All groups, therefore, received all experimental conditions, but not for the same assignments or at the same time.

Coding Procedure and Data

A content analysis of message text was conducted, with a message as the unit of analysis. Three trained coders categorized each message into a general content category and then further coded on-topic messages into categories of the two dependent variables (conceptual conflict and level of information processing) using the instruments explained below.

Messages were coded into a general content category: on-topic, procedural, social, instructor, or unclassified. *On-topic* messages are defined as those in which all or part of the message was devoted to discussing the topic or issue of the assignment. Off-topic messages include *procedural* messages about how to accomplish the discussion assignment and *social* messages that exchange expressions of greeting, gratitude, or concern; or other personal information. *Instructor* messages were posted by the class instructor or teaching assistant. *Unclassified* messages were not on topic, but did not fit into any of the other categories.

One coder coded the messages of four groups, one coded three groups, and one coded one group. To assess coder reliability, all three coded the same set of 21 messages. Percent agreement among the three coders for general content was 95.2 percent. Coders placed on-topic discussion messages into additional categories based on two constructs operationalized by the two content analysis instruments that assessed the two dependent variables: type of information processing and conceptual conflict. Conceptual conflict was measured as a proportion of disagreement present in a discussion. Agreement was 84.2 percent for instrument 1 and 84.6 percent for instrument 2.

Instrument 1 specified three levels of information processing represented in a message: none, additive, and generative. The *none* classification was applied when no relevant new information was added to the discussion (information was repeated). *Additive* indicated that the message contained additional information relevant to the discussion task. Additive information often was obtained from a source, such as the class textbook or from personal sources such as student experiences. The *generative* level of information processing was assigned to messages in which information added previously was further cognitively processed by the group. Such processing resulted in new information that did not come from an external source or from prior knowledge of group members. Messages in this category are the result of processes that transform information (such as synthesizing or inferring) and are indicative of higher-order processing.

Instrument 2 specified two major categories of dialog action: neutral/agreeing and disagreeing. Dialog actions are based on the "dialog moves" of Andriessen (2006). The Andriessen (2006) instrument specifies subcategories of the neutral/agreement category (statements, acceptances, conclusions), and the disagreement category (checks, challenges, and counters). The latter three subcategories are considered argumentative and indicate disagreement, which was interpreted as an indicator of conceptual conflict.

Results

General Message Content

A total of 914 discussion messages were coded, 830 of which were posted by students. The number of student messages coded "on topic" was 539 (64.9%). About 28 percent of the student messages were coded procedural, about 5 percent social, and less than 2 percent unclassified (see bottom row of Table 1).

The high product conditions have much higher percentages of procedural messages (over 40%) than the low product conditions (under 15%), logically indicating that requiring a written product increases the need to discuss the product (see Table 1). The high product conditions also result in fewer total on-topic posts (see Figure 1) despite the higher message counts for the high product conditions (right column of Table 1).

Table 1: Percent of messages in general categories by assignment condition.

Condition	On Topic	Procedural	Social	Unclassified	Count
High Context-High Product	47.5	40.8	8.8	2.9	238
High Context-Low Product	89.6	4.3	1.8	4.3	163
Low Context-High Product	53.1	42.7	4.1	0	241
Low Context-Low Product	80.9	13.3	5.3	0	188
% of total student messages	64.9	27.9	5.3	1.7	

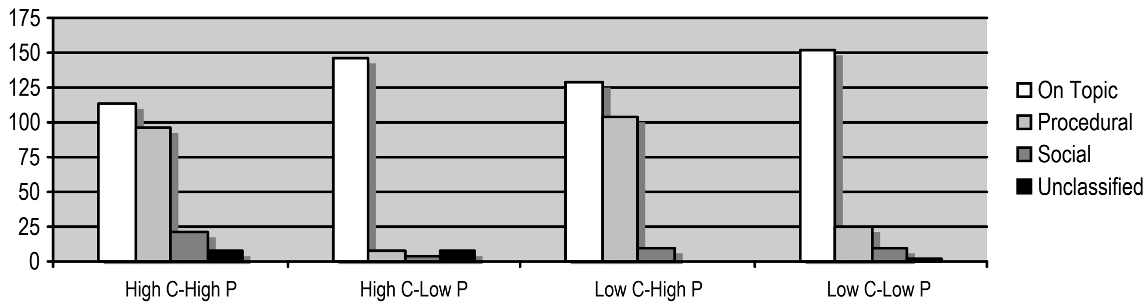

Figure 1. General category message counts for each condition.

On-Topic Messages

The eight groups posted from 42 to 99 (μ = *67.4*, σ = *20.5*, *N* = *539*) messages on topic for the four assignments. Figure 2 shows the percentages of on-topic messages for the two levels of the manipulated task variables. Differences in percentages under each condition are small, but the percentage difference of product specification is slightly greater (10.6%) than the difference in context conditions (3.8%).

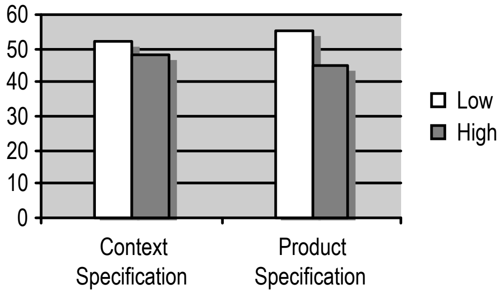

Figure 2. Percent of on-topic messages per level of task context and product specification.

Percentage of on-topic messages for each of the four experimental conditions are roughly equivalent within a narrow range of 21.0 – 28.2% (Figure 3). While the percentages are lower for the high product conditions, these data generally suggest that the degree of task context and product specification does not affect the number of on-topic messages in a discussion.

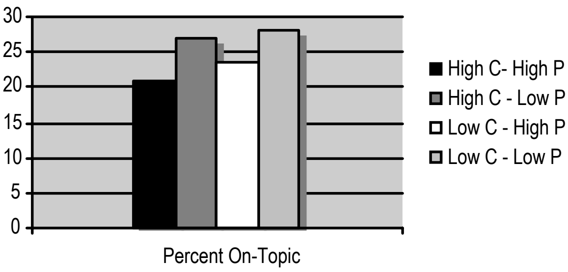

Figure 3. Percent on-task messages for experimental conditions.

Effects on Information Processing

Looking beyond mere amount of discussion, Table 2 shows the percentages of on-topic messages coded at the three levels of information processing for each experimental condition. The percentage of generative messages in the high-context, low-product condition (9.6%) is marginally higher than the narrow 7.1 to 7.8 percent range of the other conditions. Overall, this table shows little difference in the distribution of the level of processing in any of the experimental conditions and an overall generative processing percentage of only 8 percent.

Table 2: Percent information processing category for experimental conditions.

	% Information Processing Level		
Condition	Repetitive	Additive	Generative
High Context - High Product	18.6	74.3	7.1
High Context - Low Product	17.8	72.6	9.6
Low Context - High Product	7.0	85.2	7.8
Low Context - Low Product	14.5	78.3	7.2
All Messages	14.5	77.5	8.0

Table 3 displays the distribution of message processing for high and low task *context*. Each cell shows the percentage of messages coded at a level of information processing for the two levels of task context. Note that the percentages in the inner cells are based on the total number of messages coded under the low or high context conditions (280 and 259 respectively).

Table 3: Message percentages for context versus level of processing.

Context	Processing Level: Repetitive	Additive	Generative	% of Total
Low context	11.1	81.4	7.5	51.9
High context	18.1	73.4	8.5	48.1

A Pearson's chi-square test of the data in Table 3 ($\chi^2 = 5.951$, $df = 2$, $p = .051$) shows that differences in the distributions of processing level of messages due to context just miss statistical significance at the .05 level. Inspection of the percentages indicates that most of the difference in the distributions is between repetitive and additive messages, as the high context condition resulted in only one percent more generative messages. Cramer's V, which tests the strength of association, is 0.105, indicating a very weak association of context to processing. Although these results are not sufficient to draw conclusions about the effect of task context on information processing in discussions, the data do suggest little or no relationship of task context to level of processing.

A similar test of the information processing distributions of low and high *product* ($\chi^2 = 1.735$, $df = 2$, $p = 0.42$) are insufficient to reject the null hypothesis that the two levels of product specification result in the same distribution of information processing.

Effects on Conflict

Table 4 shows the percentages of neutral/agreeing versus disagreeing messages in each experimental condition. The low context conditions tend to have slightly higher percentages of messages displaying disagreement. Overall, the percentage of messages displaying disagreement was low (11.7%).

Table 4: Discussion conflict per condition.

Condition	Neutral/Agree	Disagree
High Context - High Product	90.3	9.7
High Context - Low Product	91.1	8.9
Low Context - High Product	85.2	14.8
Low Context - Low Product	86.8	13.2
All Messages	88.4	11.7

Table 5 is a cross tabulation of the percentage of disagreeing messages under different levels of task *context*. A Pearson's chi-square test of the distribution of conflict for the high/low levels of task context does not establish a different effect of context on conflict ($\chi^2 = 2.833$, $df = 1$, $p = .092$). The results indicate that lower context results in higher conflict, which is the opposite of expectations. Cramer's V is a very low .073. A Pearson's chi-square test of the distribution of conflict for high/low levels of task *product* (data not shown) does not establish a different effect of task product on conflict ($\chi^2 = 0.244$, $df = 1$, $p = .621$).

Table 5: Cross tabulation of message conflict for conditions of task context.

Context	Neutral/Agree	Disagree	Proportion of Total
Low	86.1	13.9	51.9
High	90.7	9.3	48.1

Relationship of Conflict to Processing Level

Table 6 compares the percentages of conflict to generative processing for the four experimental conditions. No pattern of conflict and generative processing is apparent by this comparison. The slight increase in conflict of the low context conditions is not reflected in a change in the percentage of generative information processing.

Table 6: Comparison of percentage of conflictive to generative messages.

Condition	Disagree	Generative
High Context - High Product	9.7	7.1
High Context - Low Product	8.9	9.6
Low Context - High Product	14.8	7.8
Low Context - Low Product	13.2	7.2

Table 7 displays the number and percentage of messages coded at the three levels of processing for the two levels of conflict. The bottom row is the percentage of disagree messages for each level of processing. Generative messages display higher levels of conceptual conflict (25.6 %) than repetitive (11.5%) and additive (10.2%) messages (Figure 4). The percentages in parentheses are for the total number of messages of the row. A Pearson's chi-square test of Table 7 data indicates that the row distributions are statistically different (χ^2 = 8.838, *df* = 2 *p* = .012). Inspection of the table shows that the difference in the distributions is due almost entirely to differences between the additive and generative categories. These data are evidence that generative messages tend to display more disagreement than messages at other levels of processing.

Table 7: Cross tabulation of the number (and percentage) of messages' processing to conflict.

	Processing			
Conflict	Repetitive	Additive	Generative	Total Messages
Neutral or agree	69 (14.8)	375 (78.8)	32 (6.7)	476
Disagree	9 (14.3)	43 (68.3)	11 (17.5)	63
Percent Conflict	11.5%	10.2%	25.6%	539

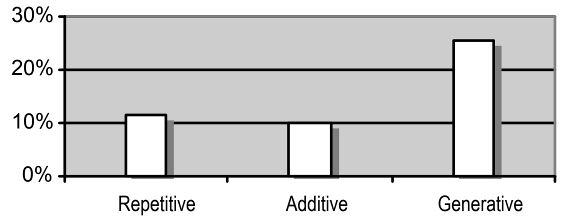

Figure 4. Percentage of disagreeing messages for three levels of information processing.

Conclusions and Discussion

Perhaps the most significant finding of this study is that both conceptual conflict and generative information processing occurred very infrequently in these discussions. Only 8.0 percent of all on-topic messages were coded generative, indicating a low level of higher-order processing in discussions of an online university class of advanced undergraduate and graduate students. This low level of higher information processing is similar to results of other studies. For example, Meyer (2003) and Garrison, Anderson, and Archer (2001) found 2.9 and 13.7 percent of messages, respectively, at the integration level of critical inquiry. The results of this study add to the growing evidence that students in online classes using collaborative discussion groups are not sufficiently engaging in higher-order thinking. Online text discussion mostly involves the acquisition of information from sources and reinforcement of existing beliefs as opposed to generation of information that is new to the group.

Significantly, disagreement is also very low (11.7%) in these online discussions. Examination of the different distributions of messages in the generative category of group information processing for different levels of conflict provides evidence that generative processing is associated with increased disagreement (Table 7). H_1 was not directly tested, but these data statistically suggest a relationship between conflict and level of information processing. If conceptual conflict is a necessary aspect of higher-order group learning, then 12 percent disagreement is disappointingly low and perhaps explains the low level of generative processing.

The results of this study do not support hypotheses H_{2a} and H_{2b}. Very little difference was observed in the number of messages posted for high and low levels of task context and product. Moreover, the number of messages posted is higher for the low conditions. The number of messages posted is a rough indicator of discussion quality, but more messages do not guarantee that discussion is qualitatively better for learning or higher-order learning. Quantity measures also do not indicate what is occurring in the discussion with respect to variables such as divergence, convergence, and conceptual conflict.

Testing hypotheses H_{3a} and H_{3b} via Pearson's chi-square test does not allow rejection of the null hypotheses that the different degrees of context specification result in no difference in conceptual conflict and information processing. However, the results from manipulation of task context had low probabilities (p = 0.51 and p = .092, respectively) suggesting that the low effect sizes (Cramer's V = .105 and .073) may be valid. These data are insufficient to establish or reject a relationship between task context and discussion conflict or processing, but suggest that more detailed task context has no large effect on conflict or processing in asynchronous text discussions.

Tests of the H_{4a} and H_{4b} hypotheses are inconclusive. The very small differences in the distribution of messages coded for the experimental conditions, however, suggest that specifying a written product has little effect on the amount of conflict or level of processing observed in discussions. Specification of a written product does seem to reduce the number of on-topic messages, as students spend more time and effort discussing how to produce the task product. Such student attention on a product may not be beneficial to the goal of increased generative information processing in collaborative discussion.

To improve CSCL discussion, researchers need to find learning environment variables that increase discussion divergence and convergence. This study did not find evidence that different levels of task context or product do affect divergence as measured by disagreement, nor were these task variables found to affect the amount and level of information processing. Instructional designers and instructors should not rely on increased task context or specification of a written group process to promote high-quality discussion for learning. This experiment did find support for the assertion that discussion conflict is related to higher-order information processing, suggesting that tasks which increase conceptual conflict are a promising means to improve the quality of CSCL discussions.

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Participation in Knowledge Building "Revisited": Reflective Discussion and Information Design with Advanced Digital Video Technology

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Abstract: Advanced tools in the realm of Web 2.0 applications have pushed forward a new paradigm for using (audio)visual media. This paradigm shift marks a starting point for theoretical reflections and empirical research on the changing nature of participation in modern knowledge building communities involving digital video. We propose a simplified model of collaborative dual-space problem solving, distinguishing online *discussion* from online *design*. Directions for future research and the educational implications of this perspective are discussed.

Introduction

Advanced tools and developments in the realm of Web 2.0 / Web 3.0 Internet technology have pushed forward a new paradigm for using (audio)visual media in computer-supported collaborative learning (CSCL). As a result, the ways in which people "watch" video information are in the process of being reshaped (Cha, Kwak, Rodriguez, Ahn & Moon, 2007): Users or learners can actively participate in knowledge building by creating and broad-/pod-casting their own digital videos (Alby, 2007), by designing complex information structures based on video, and by posting comments and 'video responses' (Benevenuto, et al., 2007). In other words: They can create entirely new patterns of video-based knowledge building in modern online-communities.

We previously investigated similar types of active video usage within the more focused context of CSCL research in formal education. For example, we have introduced digital video technologies in relation to 'rhetorical problems' for school-based education (Zahn, Pea, Hesse, Finke & Rosen, 2005) and as cognitive/collaborative tools for the support of teacher education, advanced arts and literature studies and natural science learning (e.g. the *Diver/WebDiver* project, Pea, Mills, Rosen, Dauber & Effelsberg, 2004; *hypervideo and dynamic information spaces*, Zahn & Finke, 2003; Chambel, Zahn & Finke, 2006). In our research studies we specified several functions of digital environments for video collaboration: For instance, WebDIVER™ developed by the Stanford Center for Innovations in Learning (SCIL) enables a user to direct the attention of other users to what he or she is referring to (*guided noticing*, Pea, 2006) and how technology affordances can help to structure and coordinate the joint efforts (Zhang & Norman, 1994), support a more complete and reflective elaboration than a purely oral discussion and – by making information permanent – act as a kind of group memory (Gassner & Hoppe, 2000). We also explained how advanced activities of video production or designing video-based information structures supported by digital technologies or other advanced activities of video production differ from more traditional forms of video usage in educational settings. In sum, our research demonstrates how active usage of video creates new potential for advanced knowledge building.

Here we take a more general perspective. We consider the paradigm shift associated with web-based digital video technologies as a starting point for theoretical reflections and empirical research on the changing *nature of participation in modern knowledge building communities.* Our claim is that the paradigm shift in the handling of audiovisual media requires refinements in constructivist theory approaches. Central to constructivist theory is the concept of encouraging learners to express their own knowledge in (media) artifacts rather than 'receiving' the knowledge from others. Scardamalia, for example, has long emphasized in her research the importance of establishing knowledge communities with equal rights for all learners to contribute, thus enabling participation in the communities' knowledge building processes and in the development of open information environments (as exemplified in the CSILE/Knowledge Forum project, Scardamalia & Bereiter, 2006). Likewise, Jenkins et al. (2007) have stressed the need to establish new media literacies (including social skills) needed for access to new technologies and participatory cultures for youth. While we fully agree with these theoretical perspectives, we think it necessary to shift our research focus to include empirical comparisons of contrasting types of active participation, because here contrasts are becoming more pronounced.

Generally, two major types of participation in knowledge building are well known and established (see also Alby, 2007):

- Participation in *reflective discussion and critical debate*
- Participation in *processes of information design*

While both types usually include analyses and interpretations of specific content by participants, as well as social interaction, the main difference between the two is that those participating in reflective online-discussions focus on externalizing their content knowledge in a (*text based) dialogue with discussion partners*, while those participating in design focus on expressing their knowledge by creating (multi)media elements and *structuring content for an anticipated audience according to given aesthetic standards (form) of the design environment*. This difference between discussion and design, which might be rather subtle in text-based media, becomes more pronounced in the light of the rapid advancement of technology tools reflecting the latest Web 2.0 'visions': Creating a video as opposed to merely writing a contribution to a discussion requires complex visual design activities. Thus, for example, the new usage pattern of creating video responses in the video platform *YouTube* (now the third most trafficked website in the world) clearly challenges our theoretical understanding of what it means to participate in an online community. Is a video response like a contribution to a discussion? Or is it more like visual information design? Is discussing a video the same as restructuring a video? How can we conceptualize participation in collaborative visual design with complex digital video information? Which (socio-)cognitive processes are involved in collaboratively designing audio-visual communication? How do these differ from established types of participation, such as making commentaries and contributions to a discussion? The answers to such questions can have important implications for educational practice, too. For the emergent usage patterns and types of participation, which have specific socio-cognitive effects on the learners, different theoretical models might apply to explain and predict potential benefits in educational practice. Interesting topics arise for examination into how students construct knowledge by not only viewing and exploring video, but also by responding and building knowledge with their own video-based products.

In the remainder of this contribution, by transferring the difference between participation in discussion and participation in design to complex audio-visual software environments (web-based advanced digital video technologies), we will outline a tentative model based on the assumption of dual-space problem solving processes in design. We consider this model suitable for distinguishing emerging usage patterns made possible by advanced web-based video technology. We address the related question "How can we conceive of participation in collaborative visual design with complex digital video information?" in order to gain further insights into the new paradigm of using audio-visual media for CSCL.

Online-collaboration in relation to "rhetorical problem spaces"

As mentioned above, participation in the information design processes in online communities differs from participation in discussions, because the associated collaborative activities pursue different goals: discussion focuses on dialogue with partners while design focuses on creating and structuring content for an anticipated audience according to the rhetorical or aesthetic standards of a given environment. This difference implies: When participating in a discussion, learners have to consider the content of their discussion as their problem. When participating in designing an information environment (such as a video-based web-page), learners have to take into conscious consideration *both* content *and* the audience of their knowledge product as their dual problem. The problem space they have to establish and maintain is thus a 'rhetorical' one.

The idea of writing and design as a dual space problem-solving process – a viewpoint we adopt here – was suggested earlier by research in cognitive psychology and in the learning sciences.Three major lines of research are important precedents: First, we note the cognitive approach to writing (Hayes, 1996; Bereiter & Scardamalia, 1987), which explains writing for an audience as a complex (dual space) problem-solving process, where intensive interactions between a *content problem space* and a *rhetorical problem space* lead to knowledge transformation. Second, the cognitive approach to design by Goel & Pirolli, (1992), which defines design processes as *problem solving* for an ill-defined and complex problem that needs to be defined and structured by the designer. In extending this problem-solving approach, models of design as dual space search were also proposed, for example by Seitamaa-Hakkarainen (2000). Third, constructivist/constructionist approaches to learning by designing (Erickson & Lehrer, 1998; Lehrer, Erickson, & Connel, 1994) define hypertext writing as a complex problem-solving process consisting of planning, transformation, evaluation and revision. These problem-solving approaches, including their underlying assumptions about associated cognitive processes, have been investigated and approved by much applied research in pedagogy. These approaches have also inspired a vast number of educational applications and research ranging from 'writing to learn' (Klein, 1999), to 'hypertext / hypervideo design' (Stahl & Bromme, 2004), to 'computer programming' and software design (Harel, 1991; Kafai & Ching 2001), from K-12 education to university and adult education levels. In an attempt to integrate these earlier research studies and apply them to participation in collaborative visual design in knowledge-building communities, we propose a model of collaborative dual-space problem solving (see *Figure 1*). The model certainly simplifies the complex nature of design, but can also explain how participation in discussion may differ from participation in design activities.

We assume that collaborative design in modern online communities is a collaborative process of *dual space problem solving involving intensive interactions between content and form (audience-related goals)* –

whereas discussion is usually focused on one problem space, usually the topic content. Based on this model, we assume joint *rhetorical problem spaces* in collaborative design versus joint content problem spaces in discussion (*joint problem spaces*, see Roschelle & Teasley, 1995). In contrast to participants in a discussion, who only have to establish a content space, 'designers' have to establish an additional joint rhetorical problem space and structure it according to the specific rhetorical goals, style features and rules of the media at hand. In the case of creating digital video or video-based content, these refer to the conventions of film and video, as well as the specific technologies in use.

With this simple model can find answers to the other questions posed above: Which socio-cognitive processes are involved in collaboratively *designing* visual communication? How do these differ from established types of participation, such as contributing comments to a discussion?

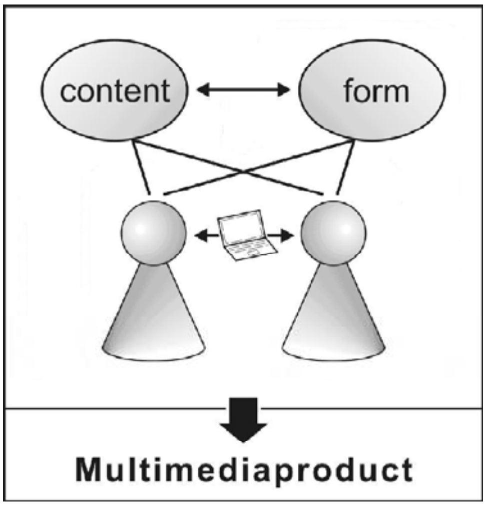

Figure 1. Integrative model of collaborative design activities as problem solving involving dual 'rhetorical' problem spaces.

To find answers to such questions, we started with conducting empirical research using WebDIVER^{TM} as a collaborative tool for analyzing video as data (Pea, et al., 2004; Pea, Lindgren and Rosen, 2006). For example, we studied the influences of WebDIVER technology affordances on socio-cognitive processes during knowledge building (in the domain of history). Here, qualitative analyses revealed how joint rhetorical problem spaces are established. In another experimental study we tested the validity of our theoretical assumptions by asking users/learners to participate either in collaborative visual design or participating in a discussion. Precisely, the participants either discussed a historical video source, or they were asked to integrate video selections from the historical video source into a multimedia product for a hypothetical student audience. We expected the 'designers' to pay more attention and consideration to both content *and* visual style of video messages than users/learners participating in a discussion, *even if they work with exactly the same materials, with exactly the same tools and in the same information environment*. The results of this study indicate that participants from both conditions (discussion and design) were similarly satisfied with the task and participants did not differ with regard to their factual knowledge in the post-test or general use of the digital tool. This proves the general effectiveness of participation in knowledge building. However, significant differences emerged with regard to participants' handling of the audio-visual source material and their collaborative strategies on a deeper level: In the design task condition, participants displayed a tendency to better recall visual information from the source material and to consider visual information in more detail. More importantly, there was a strong effect indicating that participants in the design condition integrated *both* problem spaces–the rhetorical and the content space–during their analysis of the video material, as opposed to participants in the discussion conditions. The study – despite some limitations – yielded results that are in line with a theoretical model of video based design as dual space problem solving. In particular, the findings point to extended validity of the dual space writing model of Bereiter & Scardamalia (1987) for video-based design.

Conclusion

We started our paper with the claim that newly emerging usage patterns of audiovisual communication in modern knowledge building communities (originating from advanced digital video technologies) require reflection on constructivist theory and educational practice. Particular emphasis was put on the necessity of distinguishing between contrasting types of active participation, with respect to their possible socio-cognitive effects on both theoretical and empirical learning. We proposed a simplified model of dual space problem solving distinguishing reflective discussion from (visual) design. Precisely, we hypothesized collaborative design in modern online communities to be a *collaborative problem solving process involving intensive interactions between content and form (audience-related goals) in a rhetorical problem space* – while discussion to be focused on only one problem space (content). In experimental studies, we investigated specific questions empirically and found preliminary evidence supporting these ideas. We hope that this theoretical framework stimulates future empirical research that will further refine the assumptions. There are also some educational implications important to mention in the context of CSCL: As our model suggests, different types of participation and collaborative activities (discussion and design) supported by advanced digital video technology should have different socio-cognitive effects. Without evaluating these effects as either better or worse, they apply to different educational settings depending upon different educational goals. Imagine a history lesson, for example, where a teacher asks students to analyze and interpret video as data and uses digital video technology at the computer to support collaborative learning. If the teacher's educational goal is that students learn about the historical context of video through knowledge exchange among her students, then she should probably ask students to engage in a video-based online discussion. However, if the teacher's goal is both content learning and media education (or: critical reflection of video and film as a visual information source, e.g., with videos showing historic propaganda materials), then she should probably ask the students to collaboratively design a video-based web page or something similar to be published e.g., for younger peers. Likewise, in more informal e-learning scenarios or in the realm of Web 2.0, the same technologies, the same materials but different opportunities and forms of participatory cultures (Jenkins, et al. 2007) may make a difference in the socio-cognitive processes of the users and in their (joint) focus of attention when they actively participate in knowledge building.

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Studying the effect of Interaction Analysis indicators on students' Selfregulation during asynchronous discussion learning activities

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Abstract: Selfregulation has become an important research subject during the past 20 years, especially in Technology Enhanced Learning approaches, following student-centered strategies. When designing learning activities under this scope, in a social context, the need for building supporting tools for the participants of such activities has been highlighted. We have implemented such tools, by applying Interaction Analysis (IA) techniques, in order to support the participants of asynchronous discussion learning activities. In this paper we study the effects of IA indicators on students' selfregulation. We present research findings from several implemented case studies, in order to confirm our hypothesis, that such supporting tools indeed facilitate students' selfregulation, as it was shown both quantitatively and qualitatively, thus enhancing the overall activity, as well as the collaborative process itself.

Introduction

In contemporary learning approaches, such as those under the scope of Computer Supported Collaborative Learning (CSCL), complex social and cognitive interactions take place among the collaborative members, usually increased, when compared with face to face teaching. In general, students often have difficulties in creating an image of their overall activity and that of their collaborators on a group or a community level, thus negatively affecting their motivation for improving their performance. *Metacognition*, which is the supportive axis in these cases does not only relate to cognition about cognition or cognitive processes, but to the regulation and the locus of control of one's actions (Jermann, 2004). In such cases, supporting tools are required in order to allow the students to be aware of and reflect upon their actions on a metacognitive level, thus selfregulating their actions as individuals and/or as groups, aiming at improving the quality of the product or even the collaboration itself (Dimitracopoulou et al, 2005). For regulating their activity, collaborating actors follow strategies of planning, monitoring, and evaluating their actions (Pintrich, 1999). The research field of *Interaction Analysis* can significantly contribute during these phases (Dimitracopoulou, 2008).

We have developed a discussion forum platform with integrated *Computer Based Interaction Analysis* (IA) tools called D.I.A.S. (Discussion Interaction Analysis System). Our aim is the support of all users (moderators, learners, researchers, etc) and the facilitation of discussion learning activities (Bratitsis & Dimitracopoulou, 2007; 2008), by providing appropriate sets of IA indicators among a wide range of implemented ones. In the current paper, we will investigate *the effect of IA indicators on students' selfregulation*, when involved in discussion learning activities, emerging from various implemented case studies.

The rest of the paper is structured as follows; first a brief review of the literature on selfregulation and peer support in asynchronous discussion platforms is discussed. Following, selfregulation under the scope of participating in asynchronous discussion learning activities is examined. Then the research questions negotiated in the current paper is formulated and finally research findings are presented, before the concluding discussion.

State of the Art

Our work focuses on asynchronous discussion learning activities, with peer support being the core objective. No significant work exists on studying the selfregulation effects of supporting tools based on automated interaction analysis, and especially in the case of students participating in discussion related learning activities (Bratisis & Dimitracopoulou, 2008). Research work on students' selfregulation participating in discussion forae exists, but without disposing supporting tools (e.g. Lipponen et al, 2002; Hurme et al, 2006). These researches try to study selfregulation mainly by post activity analysis of the students' interaction traces. Research on participants' selfregulation by disposing supporting tools has been conducted in other areas (e.g. Jermann, 2004; Petrou, 2005), indicating encouraging results in various settings. Overall, there is a lack of research on the study of students' selfregulation when they participate in asynchronous discussion forae and dispose supporting tools. Most of the related work refers to post-activity analysis and examination of participation and interaction patterns (based only on the post-analysis of interaction traces), without a detailed observation of students actions, and without taking into account their own point of view (related for instance to the purposes or the intentions of their selfregulative actions). In our approach, we provide students with IA indicators as supporting tools, while we focus on studying their participation and behavioral alterations, not only by the analysis of their interaction traces, but also as a result of perceiving information from these tools, as well as their own explanations regarding the effects of the tools and the purpose of their selfregulative actions.

Selfregulation in Asynchronous Discussion Learning Activities

Metacognitive skills are applied in order to manage one's cognitive skills and thus one's thinking process. According to Pintrich (1999), metacognition focuses on the regulation and control of one's actions. Three strategies are followed for that matter: a) *Planning*, b) *Monitoring*, and c) *Regulation*. On the other hand, the consideration of metacognition under the scope of intuitional evaluation of the current status, in order to define the context in which the (collaborative) activity one is participating is taking place, relates to the person's motivation to improve his/her participation in that activity (Jermann, 2004).

Selfregulation is defined as a metacognitive skill regarding a single person which is related to the development of the ability to control his/her thinking process and/or actions, in order to meet his/her predefined goals (implicit or explicit ones). Selfregulated learning is closely related to motivation in order to attain learning goals (Driscoll, 2005). Learning online is a solitary pursuit, one that requires self-directed and selfregulated learning in order to maintain motivation. Generally, learners have difficulties in creating an image of their overall activity and that of their collaborators on a group or a community level, thus negatively affecting their motivation for improving their participation and performance. Studying the selfregulation issue on a social context, three constituents can be identified: a) *Selfregulation*. Learners support themselves, taking advantage of their personal metacognitive skills, (Lipponen et al, 2002). b) *Group Metacognition*: The metacognitive reasoning is applied on a group level, evaluating the current status of the group, the existing interactions and the route towards meeting the predefined goals (Jermann, 2004). c) *Social Metacognition*: It refers to a process of mutually exploring the reasoning of the members of various groups, constituting a community, aiming at mutually understanding the current status and the pursuing goal (Hurme et al, 2006). Various theoretical frameworks exist for Selfregulation. In all of them monitoring of the learning process and reflection, mainly collaboratively among learners through social interactions, are core constituents. Thus research is focusing in the implementation of methods and tools for the support and incitement of these exact elements.

Our research focuses on asynchronous discussions which are nowadays widely used in formal or informal educational contexts, applying principles of constructivism, emphasizing in social interaction during learning activities. Recently, research is focusing towards finding methods for the evolvement and support of critical thinking through interactions, taking place within asynchronous discussions, in order to achieve high quality learning (Bratitsis & Dimitracopoulou, 2008). Such a goal requires tools, frameworks and methods for the facilitation of monitoring, and/or self-reflection and therefore selfregulation that could be supported by the automated analysis of the complex interactions that occur.

Several issues arise during asynchronous discussion learning activities, which need to be attended in order to sustain discussions and facilitate knowledge construction. Reduced user participation, off topic argumentation, untimely confrontation of arising problems and problematic user behaviors are some of them. Usually, it is the moderator (Hewitt, 2003) who designs the activity pattern, assigns roles, divides labor, monitors, advises and takes the necessary actions, in order to ensure proper conditions for high order thinking and learning, thus undertaking a huge work load which increases exponentially to the participants' group size.

In our approach, we apply IA techniques in order to implement supporting tools, constituted by visualised IA indicators, intended to influence on the level of awareness and metacognition, leading to selfregulative actions. These diagrams are presented to the students as dynamically produced feedback information, in order to assist them in reflecting upon their activity, as well as the overall activity, allowing them to selfregulate their actions and/or behavior. In asynchronous discussions, selfregulative actions can be considered any alterations of participation and overall behavior, both quantitatively and qualitatively, according to the goals, initially set by the moderator. Thus part of the moderator's work load is transferred to the students, who take more control of their learning, by regulating their action in order to properly sustain the discussions.

Research findings

Four case studies implementing a different educational activity approach have been designed *in situ*, constituting the core teaching method for the corresponding semester courses. Similar data collection and analysis methods were used, including questionnaires, experimental (allowed to review IA indicators) and control groups (not reviewing indicators) monitoring and semi-structured interviews with every participant. The most powerful indicators in matters of explanatory value were correlated with the discussions' content, in order to examine possible relations. In the current paper study *the effect of IA indicators on students' selfregulation*.

The first clear observation was *that the overall activity, both writing and reading messages was significantly increased*. In almost all cases students wrote more messages when viewing IA indicators, as shown in Table 2. In C.S. 1 (pilot study), the message writing ratio increased 107%, after IA indicators were revealed (from 45 to 93.4 messages per week). The increase of message reading activity was also confirmed by data collected during the students' interviews. More than 85% of the students, in all case studies, considered message reading an important factor within a dialogical activity. They wanted to know how many of their collaborators had read their messages (about 80% of the students gave affirmative answers to the corresponding question). When provided with the corresponding indicators, they admitted being motivated to read more messages. They felt "obliged" to read other students' messages, in the same way they wanted their messages to be read. As a student characteristically stated, "*…I have to read other students' messages, if I want them to read mine, just to be fair*". This, in turn, motivated them to write even more messages than they initially indented to, as answering comments to collaborators' ideas and opinions, other than just students they were familiar with. Moreover this factor motivated the students to be more careful when writing their messages, so as to support their content, with references and examples. During the interviews, they were asked whether seeing that some of their messages were not read by as many of their collaborators as they expected could lead them to reexamine and try to reflect upon them, in order to improve their writing. The majority of the students (50% in C.S. 1 and over 83% in C.S. 2, 3 and 4) admitted that indeed they acted so, trying at least to understand if they were mistaken in any way (e.g. short messages, off topic messages). Consequently, not only the *students increased their overall activity*, but they *tried to improve the quality of their participation* as well.

Table 1: Students' activity (message writing)

Case study	Control Group Messages	Experimental Group Messages	Difference
2	31	63	103%
3	60	74	23,33%
4	55	130	136,36%

The conclusion is that *overall the activity was enhanced, due to the IA indicators' appearance, both quantitatively and qualitatively*. This is a form of selfregulation, arising from the students' tendency to balance their activity with that of the group(s) they are members of. Motivation derives from their attempt not to stand out, both in a positive or negative manner, as the majority of the students admitted, during the interviews.

Selfregulation is a metacognitive skill related to one's ability to control his/her thinking process and actions, in order to achieve predefined goals (implicit or explicit ones). In the case of asynchronous discussions, the goal is for the discussion evolvement to reach a certain point, like an agreement, a solution or a certain extend in topic analysis. Considering that keeping a *balance between self and group activity* is an implicit goal of every person individually, that is to be able to keep up with the ongoing discussions, the IA indicators function as an additional motive for the students to regulate their actions (increasing and improving their contribution, while interacting more with their team co-members), towards this direction.

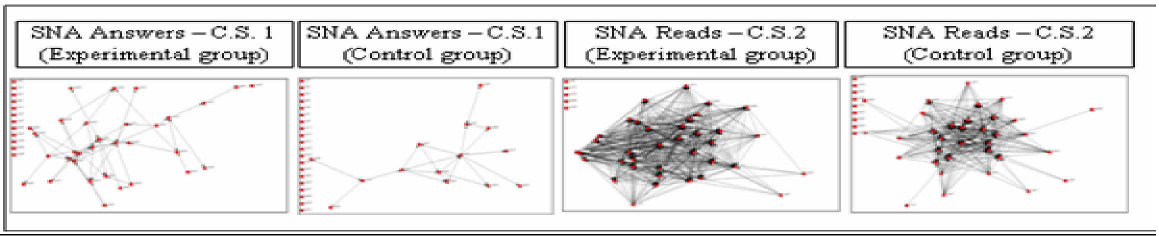

Figure 1. Sociograms representing four discussion threads

Examining selfregulation more qualitatively, we found that IA indicators, such as sociograms, motivated students to *interact with more of their* collaborators. The DIAS system produces two types of sociograms; the *SNA answers* and the *SNA reads* indicator (Figure 1). For both of them social matrices are produced, following the Ucinet DL format. For the *SNA answers* indicators, the number in the cell designated by line A and column B is equal to the number of messages written by student A as answers to messages of student B. For the *SNA reads* indicators, the number in the cell designated by line A and column B is equal to the number of messages written by student A, which were read by student B. By directly revealing each one's status with regard to the group's overall status, students claim that "*sociograms had motivated them to directly interact with more of their collaborators*", depending on the visualized parameter (reading messages or writing answers, thus reading even more of their collaborators messages). Selfregulation, in these cases, derives from the students' tendency to keep a balanced interaction with their collaborators, thus maintaining a satisfactory position within the sociogram. In the examples of Figure 1, it is obvious that the sociograms corresponding to the experimental group are denser, in all cases, depicting higher interaction. According to several researchers (e.g. Schellens & Valcke, 2005), increased social interaction among the collaborating students is a fundamental requirement for conducting constructive and thus successful learning discussions. Additionally, values of the sociograms' structural parameters were increased in our case studies for the experimental groups, indicating higher quality in the discussions, according to other researchers (e.g. Lipponen et al, 2002).

Additional evidence of students' selfregulation is the observation that *students participated in more discussion threads and in different phases of the threads' evolvement when* reviewing IA indicators. In order to demonstrate this, we examine participation data for the case studies in which the discussions were unstructured (C.S. 2 and C.S. 4). We observed that 5 out of 6 members of the experimental group in C.S. 2 participated in more than half of the discussion threads, whereas only 2 out of 6 members of the control group participated at a similar extension. Likewise, 40% of the members of the experimental group, in C.S. 4, participated in more than half of the discussion threads. On the contrary, only 2 members of the control group participated in 30% of the discussion threads and 1 participated in 42% of the discussion threads.

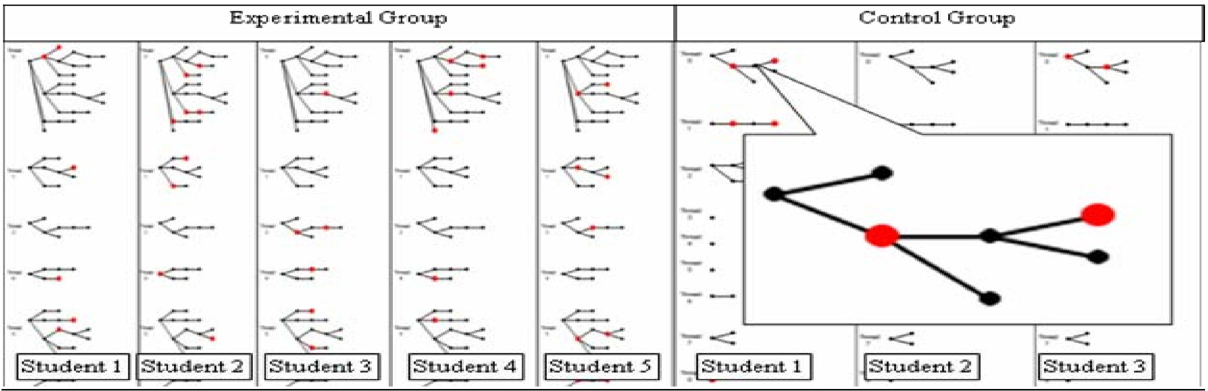

Figure 2. Student's Thread Participation indicator for eight students (Case Study 4)

In Figure 2, a portion of the *Student's Thread Participation* indicator is presented for the 5 members of the experimental group and 3 members of the control group, in C.S. 4. In this indicator, produced for every student individually, the threads of a discussion forum are displayed in a tree structure format. Each vortex corresponds to one message and the lines connecting the vortices depict the logical relation of the messages (which one is an answer to another). All the vortices are black, except the ones depicting the messages written by the corresponding student (which were colored red and have a larger diameter). The images in Figure 2 depict the aforementioned observations, regarding the difference in the students' participation ratio. Members of the experimental groups could see this indicator throughout the studies.

The participation ratio differences were significant in both case studies, substantiating our hypothesis that this indicator motivated the students to *qualitatively improve their participation* in the discussions, *by expanding their contributions in more threads*. Additionally, they admitted during the interviews that they *tried to participate multilaterally, in different phases of the discussions*, attempting to regulate their status, as it appeared through the Student's Thread Participation indicator. They did not want to write more in prior or latter phases of the discussions, but tried to keep a balanced participation pattern. As a member of the experimental group stated, "*these indicators assist you in monitoring the way you participate and understand whether you respect the discussion or not*", when commenting on this indicator, as well as the sociograms, reporting that he always tried to regulate his actions (reading - writing messages, interacting with co-members of the group) in such a manner as to maintain a correspondence with the overall activity, within the experimental group.

Moreover, as shown in Figure 2, the thread branches are deeper and wider for the five students appearing on the left hand side, whereas the ones corresponding to the three students appearing in the right side. Consequently, it is obvious from these diagrams that students who reviewed IA indicators (experimental groups) conducted more intense dialogue, which in the case of the control group indicated very poor evolvement.

Discussion

In the current paper, we wanted to examine *if IA indicators facilitate students' selfregulation and in which ways*. We consider that all the activity, motivation and behavior alterations made spontaneously by the students, when reviewing IA indicators, as selfregulative actions, especially when they seem to result in favor of the learning activity. Such selfregulation actions are the *increase of participation ratio and overall activity*, *the extension of interaction with more* collaborators and *the expanding of participation in more threads*, presented in this paper.

The importance of high rate participation and increased interaction has been highlighted as a prerequisite of qualitative dialog, which leads to effective discourse and eventually high order thinking and learning, in all the related theoretical approaches (e.g. Henri, 1992). By writing more messages and trying to post answers to as many of their collaborators as possible, thus reading their original messages in the first place, diffusion of opinions, comments and knowledge is more likely to occur. Tighter interconnection among participants is an indication of higher quality of the asynchronous discussions (Lipponen et al, 2002).

Furthermore, following the *Student's Thread Participation* indicator example, we see that the members of the experimental groups, in all cases, tried to participate in as many threads of the discussions as possible. As most of the students accepted during the interviews, their initial goal in such learning activities is always the same; "*initially participate, so as the teacher can see my name registered in the system"*. This is common behavior for students, especially in undergraduate tertiary education, leading to minimal participation. This is actually a way to "cheat" the system, in an attempt to appear active. In other cases students initially attempted to participate in the discussion in an untimely fashion, towards the end of the discussions, even writing very small, insignificant messages. This was a more sophisticated attempt to trick the simple quantitative indicators (e.g. *Number of messages written*). However, the fact is that the variety of IA indicators produced by the DIAS system did not allow them to keep trying to cheat. The provision of a set of complementary indicators, as well as the use of indicator combinations in the form of *Interpretative Schemas* could reveal all such attempts (Bratitsis & Dimitracopoulou, 2008). We suppose that the available IA indicators sets and the Interpretative Schema (assisting them to combine information derived by different indicators) helped them realize when their behavior was not the proper one and motivated them to act accordingly, regulating their actions in a way which resulted in favor of the overall learning activity. The extension of their participation in different phases of the discussions is also another example of such selfregulation. It is to be noted that overcoming simplistic research methodology approaches based only on interaction traces (usually followed in this new research direction of producing IA tools), we applied an elaborated methodological design in order to be able to extract more refined research results, that can be confirmed and explained (Bratitsis, 2007),.

In this paper we presented only two examples, in which activity selfregulation occurred by the students belonging to the experimental groups in three different case studies, among several that we observed. The similarity of the results in all these three cases provides enough evidence that IA indicators indeed enhance students' selfregulation. Concluding, we feel confident enough to say that IA indicators facilitate students' selfregulation. Students improved their participation, quantitatively and qualitatively, due to the IA indicators' presence, while working in medium size discussion groups. Our findings indicate that additional research is necessary in order to further examine their effect on the students' selfregulation skills and how these are applied in other learning situations. As we found out, IA indicators do not affect all students in the same way or the same extend. Therefore, more sophisticated research is necessary, focusing more on finding the appropriate sets of indicators for specific learning situations and contexts.

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SCAN Tools for Collaborative Learning

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Abstract: SCAN tools (Social and Cognitive Awareness and Navigation tools) inform participants about social and/or cognitive variables with respect to a group and its members. This paper describes how SCAN tools facilitate and "institutionalize" the natural processes of becoming aware about social and cognitive variables, thereby leading to adaptive behavior in collaboration. The notion of person-object relations (PORs) is introduced as the basic building block underlying both group awareness and social navigation. Four design principles of SCAN tools (response formatting, juxtaposition, aggregation/transformation, and prediction/recommendation) are discussed, and their application in CSCL scenarios is described. Finally, issues for both practical implications and use-inspired basic research on SCAN mechanisms will be explored.

Introduction

Social settings are characterized by the constant efforts of participants to coordinate their behavior with the behavior of others. In order to achieve coordination, participants of social settings have to carefully monitor the behavior of others, and they have to display markers of their own activity (Schmidt, 2002). Mutual awareness and mutual behavioral coordination were first analyzed by Heath and Luff (1992), and subsequently have become central topics in research on computer-supported cooperative work (CSCW) under labels such as "group awareness" (Gutwin & Greenberg, 1995), "team situation awareness" (Endsley, 1995), "workspace awareness" (Gutwin & Greenberg, 2002), "activity awareness" (Carroll, Neale, Isenhour, Rosson & McCrickard, 2003), or simply "awareness" (Schmidt, 2002). Of particular interest to this community are scenarios where displaying and monitoring of collaborative activities is inhibited, e.g. in net-based scenarios. The tools to provide group awareness in online scenarios are informing team members about the presence, the location, and the activities of their collaborators in virtual space, thereby enhancing mutual coordination. Research on group awareness has flourished within the CSCW community, but has only begun to be addressed in other scientific fields studying collaborative processes.

Simply being aware of others, of course, is only part of successful coordination. It is also necessary that people are influenced by what they perceive in a social setting. This influence often reflects in behavioral variables like navigation, and it does not only manifest itself in inherently social settings of direct communication, but even emerges in the absence of other people. A popular example for the latter phenomenon involves the trampled down paths over a stretch of grass that indicate to a person what might be the shortest way of navigating between places (DiGioia & Dourish, 2005). The influence that other persons' activities have on the subsequent behavior of an individual is generally analyzed under the label of "social navigation" (Höök, Benyon & Munro, 2003). Online environments can make heavy use of this metaphor because digital traces of others can be used to inform the navigational behavior of individuals (e.g. Erickson & Kellogg, 2003).

While the aforementioned examples of group awareness and social navigation refer to the influence that other persons' *activities* have on an individual, this influence can be extended to social and cognitive factors as well. People perceive what other people think, know, feel, or like ("group awareness"), and they act accordingly ("social navigation"). As an example take a researcher who presents her findings on a conference. When asked by colleagues how the presentation went, a typical answer might be "I think they liked it", or "They didn't get it". This example does not only hint at the pervasiveness of making assumptions about the social and cognitive states of others, but also illustrates the limitations of these assumptions. After all, there is no way of knowing whether the audience of the talk "liked it" because such inferences are drawn from indirect evidence, and they are drawn from only parts of the audience (e.g. someone gravely nodding, or someone else frowning). In other words, awareness about others and social navigation based on others' cognitive and social states often rest on speculation rather than reliable, or comprehensive data.

In standard net-based scenarios (computer-mediated communication, CSCW, CSCL) social and cognitive variables are even more difficult to assess. Since the 1980s the scientific investigation of net-based communication has held that the lack of social cues is one of the main barriers leading to decreased performance of computer-mediated communication (CMC) as opposed to face-to-face interaction (Kiesler, Siegel & McGuire, 1984). However, cues about behavioral, social, and cognitive states can be added to interaction through specifically tailored tools, and by exploiting the power of computers to store and manipulate those cues, we believe that awareness and navigation can be improved towards levels that actually surpass face-to-face interaction (Buder, 2007). This is the driving force behind the development of what we call SCAN tools. SCAN stands for "Social and Cognitive Awareness and Navigation". SCAN tools are designed to provide persons with systematically accrued information about how groups (or, more generally, collectives) and their members cognitively or socially relate to a given state of affairs. Put simply, SCAN tools answer the question of "How does a group and its members think or feel about something?" While making assumptions about cognitive or social states of others is a pervasive everyday phenomenon, SCAN tools might help to improve the quality of those assumptions by offering reliable data (rather than vague inferences) about groups and their members. An important point about SCAN tools is that they are developed for the participants rather than for scientific observers. In other words, SCAN tools must be designed to be relatively easy to use, easy to understand, and easy to apply in a given situation, preferably in real-time. This distinguishes SCAN tools from rather complex tools that mine for patterns in group data that will be difficult to interpret by novices (e.g. social network analysis visualizations).

SCAN tools are rather prevalent in certain net-based scenarios. For instance, group decision support systems in CSCW contexts provide awareness about social and cognitive variables (Lim & Benbasat, 1993). Similarly, many social software solutions help users navigate towards interesting content on the WWW (e.g. through bookmarking and voting systems like digg). However, SCAN tools have relatively rarely been investigated in CSCL scenarios (for awareness on behavioral rather than social and cognitive variables in CSCL see Amelung, Laffey & Turner, 2007; Bratitsis & Dimitracopulou, 2007; or Kay, Yacef & Reimann, 2007). This paper seeks to explore the potential of SCAN tools to foster online interaction among collaborative learners.

The next section describes basic mechanisms of SCAN tools. This is followed by the main section describing four design principles that are employed in SCAN tools (response formatting, juxtaposition, aggregation/transformation, and prediction/recommendation). Each principle will be illustrated using examples from CSCL research projects. A conclusion of the design principles section will compare different SCAN solutions on a number of additional variables. Finally, an outlook on practice and research of SCAN tools will be provided.

Basic Mechanisms of SCAN Tools

On an operational level we define group awareness as the perception of and knowledge about what we call person-object relations (PORs). A POR expresses the basic constituents of group awareness by linking a person to an object through a particular type of relation. First, the person constituent of a POR could either be oneself or someone else. If the person is someone else, it could either be a group member that one is interacting with (like in typical group awareness scenarios) or even a member of an anonymous collective (like in many social navigation settings). Second, the object of a POR could be almost anything: it could be a document, a movie, a forum posting, a blog entry, a single word, a TV show, a commercial product, a dancing performance - or even another person. Third, the relation of a POR refers to the type of connection between person and object. In the case of SCAN tools, the relation is of a social or cognitive nature. For instance, it could be a relation of knowledge ("Martha knows the answer"), a relation of understanding ("I have not understood this text passage"), a relation of judgment ("Steve rates this movie 9 out of 10"), a relation of estimation ("Sandra thinks the box contains 200 pellets"), of liking ("Tom likes Anita"), or of agreement ("Samantha disagrees with my latest posting"). Moreover, PORs can vary in complexity. For instance, a movie review can be regarded as a complex POR connecting a movie critic with a film through a relation of liking/evaluating. Once PORs are displayed, participants have the opportunity to achieve group awareness (by perceiving PORs, and potentially by building knowledge on the basis of PORs). If the perception of PORs leads participants to change their courses of action, social navigation is accomplished.

SCAN tools process PORs in three stages: the first stage involves the systematic registering of PORs. In the second, optional stage, PORs can be post-processed or transformed. And in the final stage, POR-based information is fed back to participants in a visual representation. There are several means of how SCAN-relevant information can be registered. Forsberg, Höök, and Svensson (1998) introduced the notion of intentional vs. non-intentional navigation mechanisms. Intentional social navigation means that a person is explicitly and consciously generating the POR (mostly through some kind of rating or voting). In contrast, non-intentional social navigation means that a POR can be implicitly inferred as a by-product from the behavior of a person.

Returning to the example of the researcher giving a talk on a conference, a simple SCAN tool might work as follows: first, audience members assess the quality of the talk by rating it on 5-point scale from highly boring to highly interesting (registering PORs). Second, PORs might be transformed into an aggregate by computing the arithmetic mean of individual ratings. And third, this information is fed back to the researcher as an overall rating. As a consequence, the person giving the talk would get a more adequate impression of whether "they liked it". Alternatively, audience members could be requested to repeatedly rate the talk while it unfolds, thereby giving immediate situational feedback. Many SCAN tools are designed to provide persons with moment-to-moment information, but of course they might also contribute to the establishment of relatively persistent cognitive structures about what groups think, know, or feel. In the latter case, the perception of PORs can be seen as related to concepts such as common ground (Clark, 1996), teamwork mental models (Cannon-Bowers, Tannenbaum, Salas & Volpe, 1995), or transactive memory systems (Wegner, 1987).

Design Principles for SCAN Tools

This section introduces four design principles that contribute to the efficiency and effectiveness of SCAN tools. Furthermore, it will be discussed which psychological processes are affected by each of these principles. The principles and the psychological processes will be illustrated with examples from research studies that tried to apply SCAN tools to settings of collaborative learning.

Response Formatting

Response formatting is probably the most basic design principle for SCAN tools. It applies both to the first stage (registering PORs) and to the last stage (visual feedback) of SCAN tool processing. A SCAN tool called Agenda Generator (developed by the first author of this paper) provides an example of response formatting (see Figure 1). This tool was used during a workshop where participants were requested to formulate topical statements about CSCL as a research field. Colleagues then read the statements. Rather than requiring participants to provide detailed feedback about a statement (unformatted response), they were asked to rate statements on two pre-defined and pre-formatted dimensions by using a slider bar (formatted response).

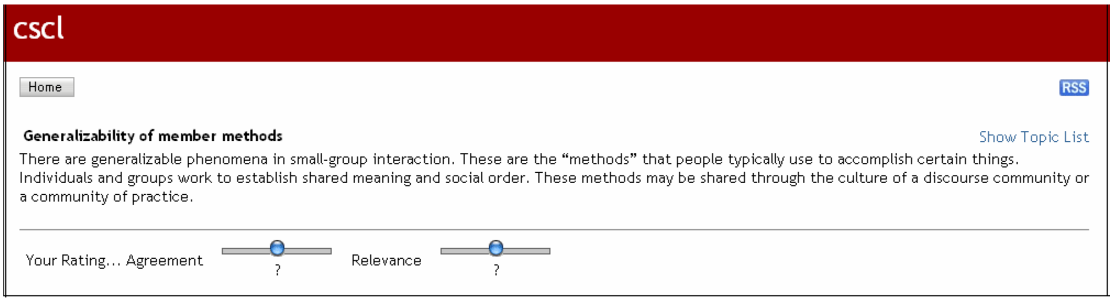

Figure 1. Response formatting in the Agenda Generator.

Virtually all SCAN tools make use of response formatting. An obvious advantage of this method is that rating objects requires relatively little effort for the interaction partners, thereby setting a low threshold for participation during the first stage of SCAN processing (registering PORs). Moreover, response formatting provides benefits for the recipients during the feedback stage. They receive a small set of values that can be processed quite easily. Reading lengthy feedback comments can be burdensome. In contrast, gleaning through colleagues' ratings for several statements is a fast and efficient way of getting an impression, thus reducing working memory load. In this way, response formatting is an efficient way of getting information across. However, it should be mentioned that response formatting might reduce the potential complexity of a POR, thereby taking away some of the richness of full interaction. The main reason why SCAN tools prefer simplified PORs is that response formatting is a necessary condition for all the SCAN design principles described below.

Juxtaposition

Many SCAN tools provide feedback on PORs that mirror the original input, whether this input was gained via intentional social navigation (e.g. explicit ratings), or through non-intentional social navigation (e.g. behavioral data). In such a case, many different PORs will be displayed to a person, and the question of how to juxtapose these PORs comes into play. If similar PORs are represented in spatial proximity, they assist learners in working out relations among these PORs. Juxtapositions make learners aware about patterns in a social setting, and they can help to guide attention towards particular aspects of the state a group is in. If two PORs with different persons, but identical objects and relations are juxtaposed (interpersonal juxtaposition), powerful processes of social comparison are triggered (Festinger, 1954; Suls, Martin & Wheeler, 2000). In addition to comparing oneself with others, interpersonal juxtaposition of PORs enables comparison between two other group members, with both types of comparison bearing the potential to lead towards regulative behavior. In contrast, if PORs with different objects and the same person are juxtaposed (intrapersonal juxtaposition), they provide an indication of a personal preference. For instance, one could see that a reviewer preferred one research paper over another. Finally, SCAN tools could employ tabular juxtapositions of PORs, thereby fostering both social comparison and comparison among objects.

Dehler, Bodemer, and Buder (2007) have introduced the PKA tool (Partner Knowledge Awareness tool) that is based on PORs where the objects are hypertext pages containing learning material, and where the relations are expressing levels of understanding. In the Dehler et al. (2007) experiment, learners individually read hypertext learning material and then rate their subjective degree of understanding for each hypertext page. Ratings are employed in a very simple, dichotomous response format that requires learners to click on a box whenever they believe that they sufficiently understood the corresponding hypertext page. After individual reading and rating, learners are grouped into collaborative dyads instructed to discuss the topic by mutually asking questions or giving explanations. The simple, dichotomous response format has the advantage of being transferable to a very simple, easy-to-grasp visual representation of PORs. In a navigation window (see Figure 2), the domain topics (each referring to one hypertext page) are listed, and the corresponding PORs for oneself (column A) and for the learning partner (column B) are represented by boxes, with colored boxes indicating that a learner has sufficiently understood the content, and white boxes indicating that a learner hasn't understood it. The vertical alignment of objects and the horizontal alignment of persons represent a tabular juxtaposition of PORs that can be used for both object comparison and social comparison purposes. For instance, across the vertical juxtaposition of boxes learners can get an overall impression of how well they understood the learning material compared to the learning partner. Moreover, since corresponding boxes for both learners are juxtaposed horizontally, learners can use the POR information to guide their interaction, with adjacent white boxes signaling a shared deficit, and adjacent colored boxes indicating shared levels of understanding. The strongest cues for structuring the interaction, however, might be provided by those cases where the color of the boxes differs. Having a white box coupled with a colored partner box is likely to trigger a question, and having a colored box coupled with a white partner box is likely to trigger an explanation. In other words, the SCAN tool is helpful for learners to tailor their contributions to a partner, a process that is termed audience design in the literature on common ground (Clark & Murphy, 1982). The experiment by Dehler et al. (2007) has shown that learners better adapted to their partners if the PKA tool was available.

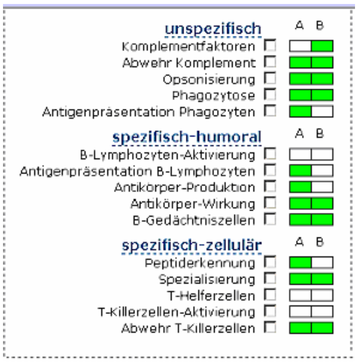

Figure 2. Interpersonal and intrapersonal juxtaposition in the PKA tool.

Bodemer and Scholvien (2008) investigated the Collaborative Integration (CI) tool for dyadic learning based on collaborative manipulation of external representations. This SCAN tool is an extension of earlier work on active integration (Bodemer, Plötzer, Feuerlein & Spada, 2004), an instructional method to foster individual understanding by requiring learners to drag and drop pre-formatted content elements (e.g. variable labels) onto corresponding slots of a graphical representation. In the CI tool, dyadic learners perform the active integration task simultaneously and independently, all the while they are communicating with each other. Each learner sits in front of a computer, and the screen displays a shared image of the external representation. The representation (e.g. a picture) contains several blank slots that have to be filled by dragging and dropping content elements onto them. However, instead of single slots the representation contains juxtaposed pairs of slots, one for each learner. While a learner fills his or her empty slots, the learning partner performs the same task. The juxtaposition of slots works similarly as with the PKA tool, i.e. learners can easily see those parts of the representation that are unaddressed as of now (two blank slots), and they can see if they agree with their partner (two slots with identical content elements dropped onto them). Most importantly, the CI tool makes conflicts visible, viz. if two corresponding slots contain two different content elements. While these mechanisms of the CI tool are similar to the PKA tool, there are notable differences as well. For instance, the Collaborative Integration tool does not require learners to explicitly rate their understanding of particular concepts, i.e. PORs are revealed through the interaction itself. Moreover, collaborative integration provides SCAN-relevant information in real-time as the dyadic interaction unfolds. It was shown in an experimental study that dyadic interaction and communication had a particularly strong focus on the conflicting content assignments that arose during collaborative integration. Seeing these conflicts between solutions provided strong cues for the learners to address the conflict and achieve a shared understanding (Bodemer & Scholvien, 2008).

Juxtaposition as a design principle for SCAN tools works best if the number of persons or the number of objects to be displayed are limited, and if the PORs are relatively simple. But even with very complex PORs SCAN tools can be effective, as was shown by Engelmann and Tergan (2007). Their KIA (Knowledge and Information Awareness) tool juxtaposes complex concept maps that group members have individually created prior to interaction. Although it is somewhat more difficult than with the PKA or CI tool to work out and compare PORs among collaborators, an experimental study has shown that the KIA tool led to better problem-solving performance of groups. All three tools clearly indicate that systematically requesting learners to generate PORs (through rating or through learning activities) is superior to having learners work out and infer PORs from interaction itself (for further discussion on these three Knowledge Awareness tools see Engelmann, Dehler, Bodemer & Buder, submitted).

Aggregation and Transformation

It was already noted that POR processing can involve up to three stages (registering, transforming, and visualizing PORs). The PKA tool, the CI tool, and the KIA tool are examples for SCAN tools where the original input (ratings, actions, concepts) directly map onto the output PORs, i.e. the second stage is missing. In contrast, some SCAN tools aggregate across several PORs, or even transform the feedback based on aggregated data. Through aggregation and transformation SCAN tools can become very powerful because they make information visible that is difficult or almost impossible to achieve in face-to-face or standard CSCL interaction. For example, aggregation can be done for one object over several persons by computing an average value of a group. This opens a window into group cognition, as the SCAN tool now literally displays what a group is thinking about a given state of affairs. Similarly, single PORs can be added for one person over several objects. As a consequence, learners can compare with other learners on an aggregated variable. By these means, SCAN tools can reveal patterns in interaction that provide powerful cues for learners to adapt their behavior.

Buder and Bodemer (2008) have developed a class of SCAN tools (termed augmented group awareness tools) for the support of controversial CSCL discussions. In their scenario, small groups discuss a conflicting issue, and each text-based contribution in their threaded discussion can be rated by the collaborators on dimensions such as agreement or novelty. Augmented group awareness tools consist of a graphical representation that displays the contributions as dots in a Cartesian coordinate system (see Figure 3). The representation is updated in real time when a contribution is rated by a person. Using the rating dimensions of agreement and novelty, learners can see how much the group agrees with a given contribution, or how relevant (and novel) a group considers a given contribution to be. In addition to providing almost instantaneous feedback about one's own contributions, the SCAN tool helps learners to identify crucial contributions in a discussion. In an experimental study involving discussions between a single learner advocating a correct viewpoint and an incorrect majority sub-group it was shown that the SCAN tool strengthened minority influence.

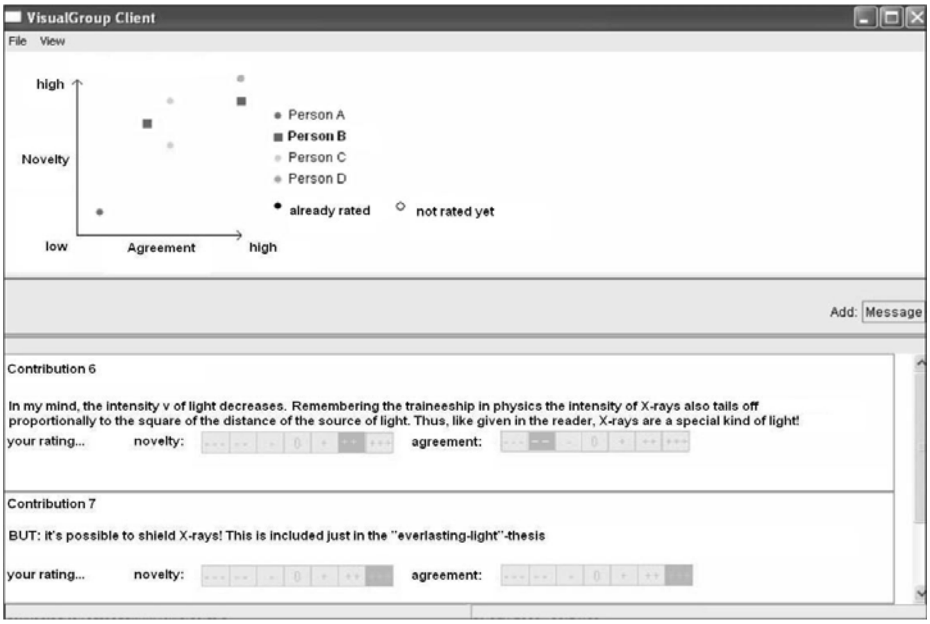

Figure 3. Aggregated and transformed PORs in Augmented Group Awareness tools.

In contrast, the SCAN tools investigated by Kimmerle, Cress, and Hesse (2007) foster social comparison processes among persons by aggregating over several objects. The objects in this case were small pieces of information that could be either shared or withheld, and the SCAN tools compute a level of cooperativeness for single persons based on the aggregation of multiple individual decisions about sharing vs. withholding information. This is an example for non-intentional social navigation since the level of cooperativeness was computed from a set of behavioral data. As a result, the SCAN tool visualizes an individual's level of cooperativeness in comparison to other group members. In an experimental study it was shown that participants increased their level of cooperativeness over time after receiving bogus feedback about high levels of partner cooperativeness. The study also compared individualized feedback (separate levels of cooperativeness for each partner) with group feedback (instigating comparison between an individual level and the group average level, thus representing a double aggregation over both persons and objects). Interestingly, only individualized feedback increased levels of cooperativeness. This finding is in line with the observation that awareness tools are particularly effective if they instigate mutual accountability and "social translucence" (Erickson & Kellogg, 2003).

Most SCAN tools that employ aggregating mechanisms transform the aggregated PORs into arithmetic means. However, one could think of many other ways of transformation. The Agenda Generator tool introduced in the section on Response Formatting employs an alternative means of transformation, viz. the use of statistical dispersion among data. To recall the scenario, members of a group are requested to formulate statements about a given topic. Other group members rate these statements on dimensions such as agreement and relevance. The Agenda Generator then displays the statements as a list that can be sorted not only by average agreement and average relevance, but also by degree of conflict. Degree of conflict can be computed as the standard deviation of agreement ratings. If a statement receives ratings ranging from high to very low agreement, the standard deviation of agreement ratings will be comparatively large, and the statement will be particularly controversial. The Agenda Generator is designed in a way that the most controversial statements can be listed at the top (or bottom) of the statement list, thereby providing helpful cues for a group about interesting topics to discuss. Along the same lines, different aggregation and transformation mechanisms could be employed for SCAN tools. For instance, correlations of PORs could be used to compute similarity among different objects or different persons. SCAN tools might even perform real-time higher-level analyses on POR data, e.g. cluster analyses, factor analyses, or multidimensional scaling techniques. However, it should be noted that the feedback should be provided in ways that are easy to understand and use for learners.

The tools described thus far use relatively simple, low-tech solutions towards generating SCAN-relevant data. However, a number of SCAN tools have been suggested that rely on much more complex forms of aggregation. E.g., SCAN tools developed in the ARGUNAUT project (De Groot et al., 2007) are designed to identify typical patterns of interaction in graphical e-discussions. The tool analyzes temporal conjunctions ranging over several persons (the group members), several objects (discussion contributions), and several types of relations (pre-defined message types). If crucial patterns are discovered in interaction (identified through machine learning and/or pattern matching algorithms), this information will be fed back to a discussion moderator who can take several courses of action. A second example for complex aggregation and transformation mechanisms can be found in the suite of SCAN tools that Teplovs, Donoahue, Scardamalia, and Philip (2007) have developed as add-ons for the Knowledge Forum. Among these tools is a Semantic Field Visualization that uses very fine-grained PORs (with the objects being single words used by learners) and extracts similarity among texts and/or learners through Latent Semantic Analysis. A third example of complex aggregation can be found by Janssen, Erkens, and Kanselaar (2007). Their Shared Space tool analyzes linguistic markers from chat logs in real time and aggregates these data over the entire group. As a consequence, the tool indicates the collective degree of conflict and feeds back this information to the group as the interaction unfolds.

These examples illustrate that there is an enormous variability among the aggregation and transformation principles used in SCAN tools for CSCL. However, many areas for the application of SCAN tools are still unexplored. For instance, there are currently very few developments geared at capturing the temporal dynamics of SCAN-relevant information. While analysis and feedback on navigational trails is quite a common method to inform groups about behavioral variables (e.g. Börner, Hazlewood & Lin, 2002), the authors are not aware of many similar applications for tracking social and cognitive variables over time (a notable exception being a SCAN tool for the Knowledge Forum indicating vocabulary growth over time; Teplovs et al., 2007).

Prediction and Recommendation

A very promising area for the development and research of SCAN tools involves tools that generate new PORs based on existing patterns of interaction. The immediate benefit of predictions and recommendations is that the tool essentially takes the role of a highly informed, additional learner or mentor. In the best case, SCAN tools can assist learners in getting a new perspective on a collaborative setting by explicitly pointing out areas of interest (other persons or other objects), and helping learner to overcome habitual responses. Moreover, knowing about persons that will be interesting to interact with can help to build and re-structure transactive memory systems and teamwork mental models.

In fields outside of CSCL, tools that explicitly suggest new PORs on the basis of interactional patterns are quite common, e.g. in the case of recommender systems. Recommender systems employ algorithms to determine similarity between persons or between objects in order to predict new PORs. For instance, the recommender system MovieLens (Konstan & Riedl, 2003) predicts movies that a target person will like, but hasn't seen yet. Applying these principles to CSCL scenarios seems to be a very promising approach. However, in our field SCAN tools that predict PORs and recommend courses of action are still in its infancy. For instance, Harrer, Malzahn, Zeini, and Hoppe (2007) used social network analysis (SNA) in order to generate person recommendations (whom to work with) and object recommendations (emerging trends) in a large-scale community. However, social network analysis is limited to showing existing patterns of interaction rather than non-existent, interesting connections. Harrer et al. (2007) tried to overcome this limitation by introducing additional representational schemes (e.g. knowledge maps or ontologies) that are combined with the SNA representations to predict new PORs.

An easier approach towards prediction and recommendation might be to rely on SCAN tools that use intentional social navigation (i.e. explicit ratings by learners) since these can be tailored to the situation at hand. For instance, the Agenda Generator described above is a very simple tool that uses rating patterns to derive recommendations about topics (objects). Likewise, Augmented Group Awareness tools (Buder & Bodemer, 2008) could be adapted to compute similarity ratings among persons, thereby generating recommendations for group compositions (based on maximized similarity or dissimilarity).

Conclusions

This paper attempts to compare various SCAN tools by couching them in the terminology of person-object relations (PORs). It has provided examples from CSCL scenarios that rely on very different persons, different objects, and different types of relations. Firstly, some tools described above provide feedback about individual persons (oneself or other group members), while other tools only provide feedback about aggregated groups. Secondly, SCAN tools differ in the objects they provide feedback on. Some tools use objects that are external to the collaborative group (e.g. pages of learning materials in hypertext formats, Dehler et al., 2007; elements of a graphical representation, Bodemer & Scholvien, 2008; concepts and relations of a domain, Engelmann & Tergan, 2007; small pieces of information, Kimmerle et al., 2007). In contrast, the objects of other SCAN tools are products of the collaboration itself. These can range from macroscopic objects like entire documents (Harrer et al., 2007) over smaller objects like discussion contributions (Buder & Bodemer, 2008; De Groot et al., 2007), up to very small units like words being used (Janssen et al., 2007; Teplovs et al., 2007). Thirdly, there is a whole range of social and cognitive relations revealed through the SCAN tools. Some relations are social in nature (e.g. ratings of agreement), others focus on cognitive variables (e.g. indicating the degree of understanding, or expressing one's knowledge through collaborative integration). Interestingly, some SCAN tools derive social and cognitive variable from basic behavioral activities. For instance, simple decisions to share or withhold small pieces of information can be aggregated to yield levels of cooperativeness (Kimmerle et al., 2007), or linguistic markers used in chat discussions can be aggregated to yield levels of conflict in a group (Janssen et al, 2007).

In the introduction it was mentioned that successful coordination requires both group awareness and social navigation. The design principles of response formatting, juxtaposition, and aggregation/transformation subserve the group awareness function. Response formatting enables participants to register PORs in fast and efficient ways. Juxtaposition of PORs provides a means to compare persons and/or objects. Aggregation and transformation provide the most comprehensive answers to the question of "How does a group feel and its members think or feel about something?", thereby opening a window into representational and computational aspects of group cognition. SCAN tools make use of the whole range of principles to facilitate group awareness.

With regard to the navigation (or adaptation of behavior) function of SCAN tools there is an even greater variability among tools. Some SCAN tools provide awareness about group states, but present little in the way of affordances to actually adapt one's behavior. For instance, Semantic Field Visualization (Teplovs et al., 2007) shows the similarity among texts and among authors, but this kind of information does not explicitly prompt regulative action. Most SCAN tools described above propose indirect effects of group awareness on navigation. By making aspects of interaction salient and aware, these tools often implicitly suggest potential courses of action to a group without strictly enforcing them. This is very much in line with early conceptualizations in the CSCW literature stating that group awareness denotes "those practices through which cooperative activities are somehow tacitly and unobtrusively aligned and integrated" (Schmidt, 2002, p. 287). However, the design principles of prediction and recommendation show that SCAN tools can be much more directive with respect to the navigation function. The different degrees of directivity among tools were addressed in the distinction between mirroring tools, metacognitive tools, and guiding tools (Soller, Martinez, Jermann & Mühlenbrock, 2005).

The Future of SCAN Tools

Over the course of the last few CSCL conferences an increasing number of studies have employed and investigated SCAN tools. It is not unlikely that this trend is going to continue. New SCAN tools will be developed, and some scholars might apply the SCAN metaphor to entirely new fields involving variables like affect, motivation, or mutual regard (e.g., Murray, 2007). However, for the field to mature some significant advances have to be made. First of all, the field is still lacking demonstrations of how SCAN tools can contribute to actual CSCL classroom practice. For instance, as of now there is no learning environment that makes heavy use of SCAN tools. Such an environment could employ a whole range of SCAN techniques like ratings of learning material, polls on discussion topics, collaborative highlighting methods, mutual peer assessments, and learner expertise maps. Ideally, such an environment would be tested and refined through approaches of design-based research.

In order to improve the practice of SCAN tools, we need more use-inspired basic research as well, both with respect to the group awareness function and the navigation function of SCAN tools. Among the open research questions are the following:

- What kind of group awareness information do learners prefer in collaborative settings? For instance, Yoon (2007) has found that in seeking partners for discussion learners prefer collaborators with opposing rather than congruent viewpoints.
- How does group awareness develop over time? For instance, Sangin, Nova, Molinari, and Dillenbourg (2007) have found that the dynamics of group awareness are quite complex, as learners' use of SCAN-relevant information is partially dependent on the use of the same information by their collaborators.
- What is the relative efficiency of intentional vs. non-intentional metaphors of social navigation? For instance, requiring learners to explicitly rate on a given state of affairs can be tiresome, and might distract from the task at hand. However, through intentional social navigation meta-cognitive and elaborative processes might be prompted, and these could provide an important link between the group awareness and the navigation function. In contrast, non-intentional social navigation mechanisms are elegant and non-distracting, but at least for SCAN tools that involve complex aggregations and transformations they might lead to lower acceptance by group members. Will learners let the computer "tell" them in what state a group is?
- How directive should SCAN tools be? For instance, Miao and Koper (2007) have supported the group awareness function of SCAN tools via a scripting approach that guides learners through sequences of mutual peer assessment. Taking this idea a step further one could think of SCAN tools that even script the navigation function. However, this would massively interfere with the notion of learner autonomy.
- Could SCAN tools inhibit collaboration? There are a number of unexplored, potential side effects of SCAN tools, both on the individual and the group level. For instance, providing feedback about individual learner performance might lead to evaluation apprehension. On a group level, making problematic issues aware might aggravate rather than alleviate these issues. Feedback research in educational psychology (e.g. Shute, 2008) might offer some solutions on how to give feedback that is both informative and supportive.

While this list of questions is far from comprehensive, it might provide some building blocks that can be used for building an agenda on SCAN tool research in CSCL. As of now, SCAN tools look like a promising candidate for enriching our repertoire of tools to foster the practice of CSCL.

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Creating discussion threads graphs with Anagora

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Abstract: We present Anagora, a graphic tool tracing discussion threads along a time axis. Anagora displays overlapping discussion threads over time on a single screen. Its special feature is to calculate the best resolution for a forum to fit on a screen by choosing the most appropriate time scale. Anagora is used to generate views of fora or forum thumbnails. Several discussion fora coming from e-learning platforms illustrate how Anagora is used by tutors and moderators to monitor students' collaborative work.

Introduction

In the framework of the Calico[1] project, a French collaborative research project joining researchers, teachers and teacher trainers, a number of tools were designed to study and monitor computer mediated communication. Bulletin boards transcripts, also called fora or computer conferences, can be loaded on the Calico platform and processed by quantitative and qualitative tools. Among them is Anagora, tracing discussion threads along a time axis. A number of solutions are proposed in literature to visualize discussion threads, social interactions and sometimes provide link to content (see Dimitracopoulou *et al.*, 2005 for a review, and Bratitsis & Dimitracopoulou, 2008 for methodological issues).

Discussion threads are convenient to assess activity on an educational forum and are used to monitor them (e. g. Gerosa, 2005; Chen & Vassileva, 2006). Beyond the educational settings, researchers tried to provide a view of discussion threads with scalable tools, to cope with very large Usenet fora (Turner *et al.*, 2005), or to display discussion images on small screens (Engdahl *et al.*, 2005). Some researchers devised ways to cope with hierarchical, multilevel contexts in education (Enriquez, 2007). Taking the time axis in consideration to show the overall activity of a community by showing concomitant active threads was also tempted (e.g. Huynh Kim Bang & Bruillard, 2005).

Anagora provides bar graphs to visualize overlapping discussion threads over time on a single screen. Its special feature is to calculate the best resolution for a forum to fit on a screen by choosing the most appropriate time scale (corresponding to days, decades, months or more) according to data. It thus provides a kind of thumbnail image, which is used to represent a forum on the Calico platform in reduced format. The full-size image is also used to monitor discussions in computer-mediated communication. Anagora is also fit to deal with multilingual data through Unicode. It effectively handles French, Greek, Vietnamese and English language.

In this paper we present this visualisation tool and show some examples of Anagora use to explain how it helps tutors in interpreting small and large educational discussion fora, in distance education.

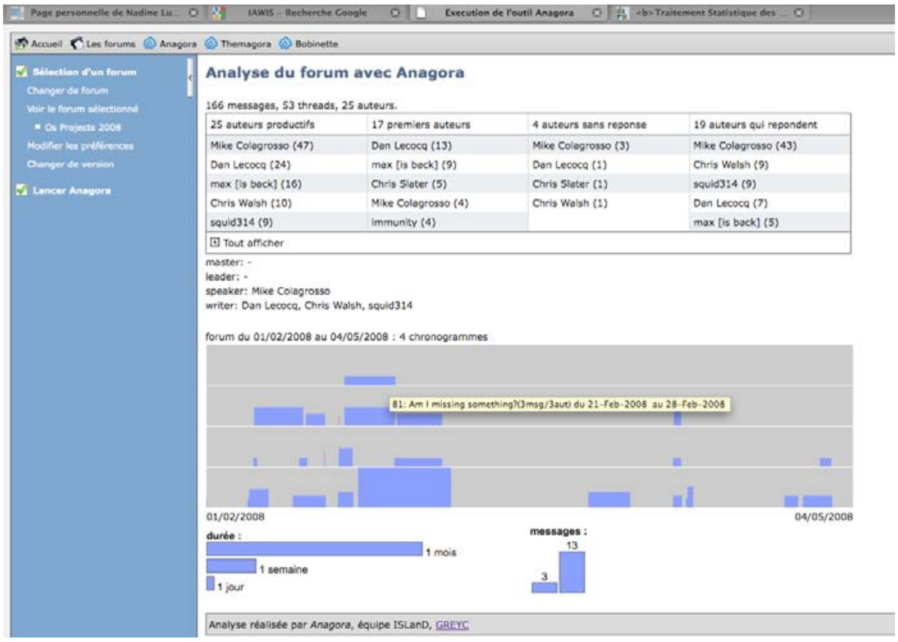

Figure 1. The Calico platform interface with name of thread activated

Discussion threads and chronograms

Anagora highlights high activity in a forum, through discussion overlap. A discussion thread (on the same topic) is shown as a red block, horizontally spreading according to its duration, and vertically spreading according to its number of messages. When dragging the mouse on a block, the title of the thread appears along with dates as shown in figure 1 showing a general view of the French interface. Discussion threads are displayed on rows, while they are sequential. The first row is placed at the bottom of the screen, simultaneous discussion threads are placed above. One row depicting temporally distinct threads is called a chronogram. There are as many chronograms as overlapping discussions within a given time frame. The vertical axis is then called the chronogram axis. In figure 2 there are at most 5 ongoing discussion threads at the same time, during the first month and then the third one. The time scale indicates that the minimal unit in this case is the day.

Graph scalability

The need to address scalability came with textual analysis of fora, which can vary to large extents in duration, number of threads, number of participants and number of posts (Lucas & Giguet, 2008). The same concern prevailed when designing Anagora.

To draw Figure 2, discussion threads including at least 3 messages are represented, otherwise, they are omitted for the sake of clarity. This threshold was chosen because the canonical exchange pattern is made of three posts: a question, an answer and an acknowledgment (thanks or OK message). The actual number of threads is indicated above the graphs with some other quantitative metadata. Depending on the original configuration of the forum, discussion thread metadata are used when available, else, in case of flat list fora, replies with the same message title are considered as forming a thread.

The scale is calculated to fit in the screen, so that, as will be seen in examples, a short forum over a month or so will be drawn in the same screen window, thus it will look expanded as compared to Figure 1, while a forum spreading on years will seem shrunk.

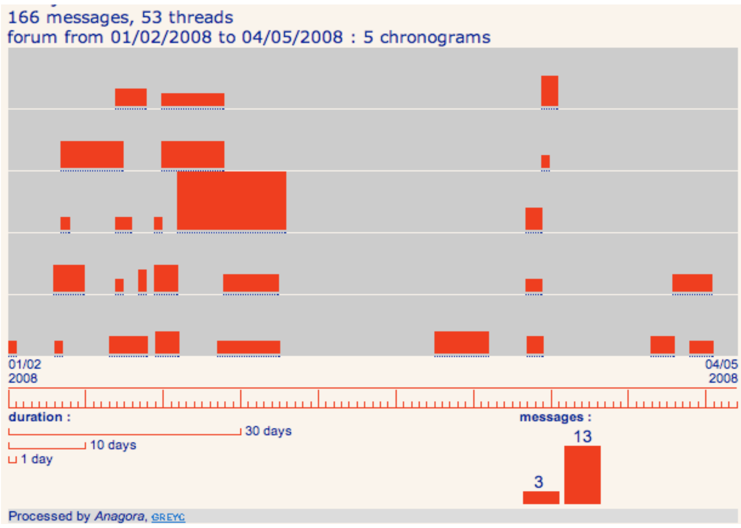

Figure 2. Chronograms for a discussion forum over 3 months (OS projects 08)

Interpretation of users' behaviour

Interpretation varies with the nature of tasks, number of participants, expected behaviour, time allocated for each task etc. We report on two experiments in entirely distant education, using Anagora along with other tools.

Small group collaboration

Anagora was used to monitor collaborative activity in small educational fora, with three students cooperating for an assigned task for about one month. Two groups are compared for two tasks each.

The first group, called DUTBM, exhibits a fairly typical behaviour in collaboration (Fig. 3 and 4). For the first task, discussion threads tend to overlap at the start of the forum, with many topics being discussed at the same time, thus creating 4 chronograms. This pattern is common when students share ideas on work packages. Later, students start working on their allotted part and activity decreases in the forum. Three overlapping discussions are seen in the final period before the assignment is sent to the tutor.

For the second task, this group encounters more difficulties at the beginning and discussions pile up for nearly a month, before consensus is reached (Fig. 4). Interactions are short thereafter and only brief threads (not drawn) are needed before the assignment is sent to the tutor.

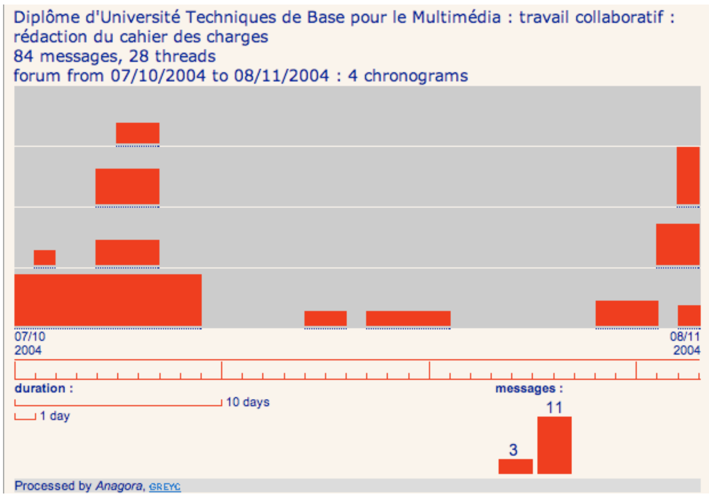

Figure 3. Chronograms for a small group (DUTBM task 1) with typical peaks of simultaneous discussions at start and before the end of the forum

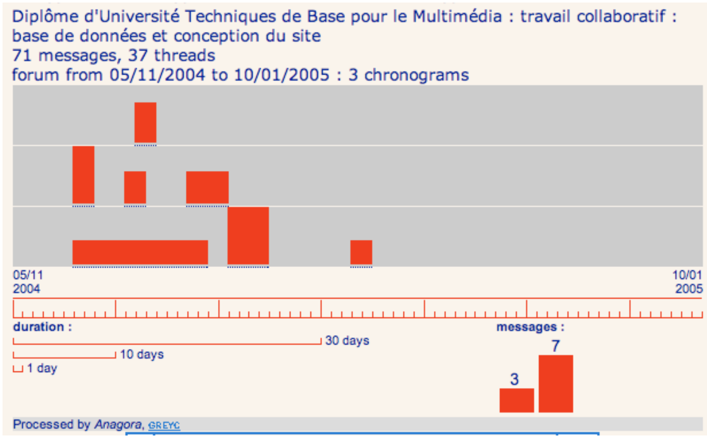

Figure 4. Chronograms for a small group (DUTBM task 2) with simultaneous discussions at the beginning

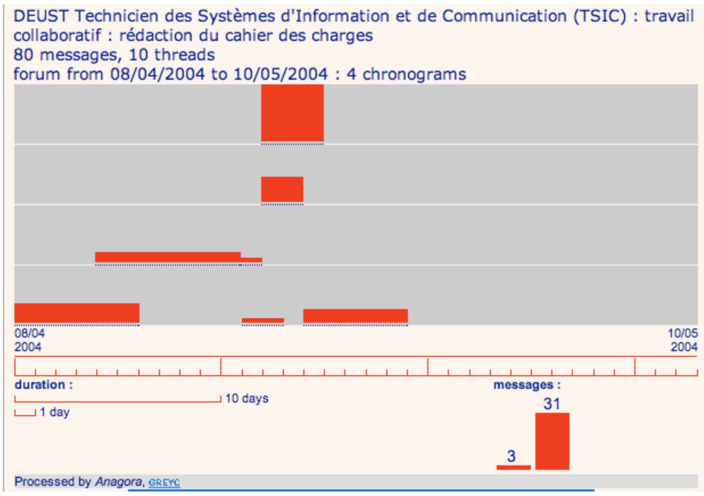

Figure 5. Chronograms for a small group (DEUST task 1) with simultaneous discussions in the middle

A different behaviour can be seen from the simultaneous discussions going on in another group called DEUST (Fig. 5 and 6). For task 1, the number of chronograms is four, same as for the first group. But these different discussion threads start in the middle of the task, hinting that tuning between participants has not been successful. For task 2 this pattern is reinforced with as many as 8 chronograms shown in the middle of the task. Dissension occurs in this case. Interpretation is backed by access to the discussion thread.

Moderators appreciate the juxtaposition of figures 3 and 5 and 4 and 6 (for the same task) to judge the distribution of chronograms for different groups.

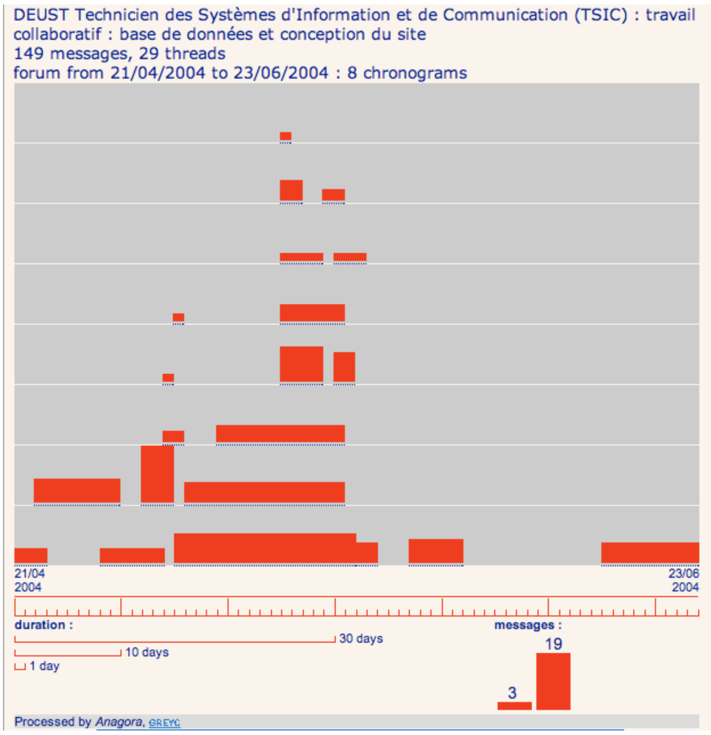

Figure 6. Chronograms for a small group failing to collaborate (DEUST task 2)

Long term collaboration

In a different experiment, a group of student in distance education was followed over three years, the average time for them to complete a standard two-year course. Participation in discussion forum for each curriculum was not compulsory, but was active. In figure 7, the scale is different from the short discussions just explained above. The minimal unit of time here is one month (30 days) instead of 1 day.

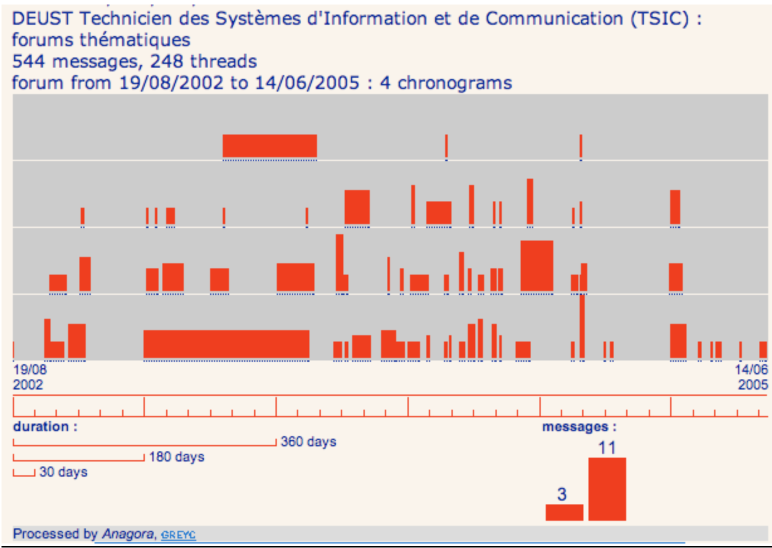

Figure 7. Chronograms for a 3 year period (DEUST)

In this case, the number of simultaneous threads reached four after eight months. The length of threads after roughly six months is fairly long, which is explained in some instances by recurrent complains about course organization. The length of threads tends to decrease in the second year, while the number of exchange per thread increases (one can see many tall and thin threads). In the last year, three simultaneous threads are seen, corresponding to partners joining into project taskforces.

Discussion and perspectives

Visualization tools for educational fora become more and more sophisticated (Mazza & Dimitrova, 2007). Related work in the domain of adaptive scalability for quantitative analysis of educational fora is recent. May *et al.* (2007) work on log traces of students' activity and address the same problem of meaningful units. Cress (2008) offers an elaborate mathematical approach to deal with levels and scale.

While Anagora is much less sophisticated, it is also fairly easy to use. Users in the Calico group generally liked the Anagora view of fora: this representation allows display of several groups at a time, allowing comparisons of group progress in computer based education. They also used these compact representations as thumbnails to represent the files on the Calico platform. This platform can be accessed at http://www.crashdump.net/calico/, and Anagora can be tested on external data as well.

However, some improvements are needed. The number of chronograms is decided with a fixed threshold of 3, but this value should also be calculated by the program, according to length and number of participants in the forum. The thumbnail effect should be applied both on the time axis and on the chronogram axis.

Anagora provides the best resolution for a forum to be seen on a single screen. Alternatively, visualisation for comparison of (images of) discussion threads in a fixed span of time could be provided. This would amount to give a constant ratio for geometric representations and duration, like in cartography for space. For instance, in the present state in figure 3, a thread spreading on ten days has the same dimension as a thread spreading on 28 days in figure 4 and this could be misleading. For tutors who manage fairly fixed time allotments in course management, it would be useful to compare the progress of different groups by keeping geometrical dimensions anchored on a constant representation of time. Last, interactivity should be provided through hyperlinks allowing thread content visualization and individual messages popping up inside the thread.

Endnotes

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Self-regulation in ACT: A case study in peer-assessment activities

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Abstract: Having as an objective to support students in collaborating/communicating fruitfully with respect to the underlying collaborative learning setting, we developed ACT, a synchronous communication tool which supports mechanisms for students' self-regulation as well as for the adaptation and personalization of the communication. The self-regulation mechanism enables the diagnosis and the evaluation of students' collaborative behavior both at the cognitive and social level and provides feedback at awareness, metacognitive and guiding level. The use of ACT in the context of a peer-assessment activity showed that the tool can help students in self-regulation and improve their collaboration behavior.

Introduction

Current trends in educational practice emphasize the social dimension of learning and consider assessment as one of the most powerful educational tools for promoting and motivating effective learning (Pellegrino, Chudowsky, & Glaser, 2001; Vosniadou, 2001). Regarding assessment, the exploitation of alternative methods such as peer-assessment may make the assessment process a valuable learning experience (Dochy & McDowell, 1997). In peer-assessment, the author and/or the assessor may be individual or group of learners. In a computer-based educational setting, it is crucial to support and sustain productive collaboration/communication and appropriate communication means are required to support group members to productively collaborate and propose, articulate, evaluate and refine their ideas.

The structuring and regulatory approaches contribute to the development of tools that support and guide students in the development of communication skills and in having a fruitful collaboration (Jermann, Soller, & Lesgold, 2004). In the context of text-based synchronous communication, the structuring of the collaborative process is achieved following the structured dialogue which is implemented through sentence openers. Researchers state that different forms of dialogue could be more appropriate for different kinds of activities and the available communication means could possibly be tailored to the underlying learning setting (Lazonder, Wilhelm, & Ootes, 2003; Soller, 2001). As far as the regulation approaches are concerned, current research efforts focus on the design and implementation of interaction analysis (IA) indicators that mainly concern the social dimension of collaboration and the provided feedback is given at one level i.e. awareness or metacognitive or guiding level (Dimitracopoulou et al., 2005). In the literature of the feedback field and educational practice, it is stressed that feedback should focus on student's progress, provide guidelines for improvement and be available in alternative forms and levels in order to cover the diverse students' preferences and abilities (Mason & Bruning, 2001; Vosniadou, 2001).

Our efforts aim to extend research in the CSCL field, by developing a synchronous communication tool with adaptive capabilities, called ACT (Adaptive Communication Tool) in order to support and promote students' collaboration/communication. In ACT, the collaborative learning setting includes the activity, which may have one or more subactivities and the collaboration model, which determines the number of the group members, whether group members are going to collaborate having the same duties or undertaking different roles, the duties of each role and the role that each member undertakes as well as who is going to act as the moderator of the group. The collaborative activity serve a specific learning goal, which is further analyzed to outcomes of Comprehension, Application, Checking-Criticizing and/or Creation level. ACT supports both the free and the structured form of dialogue; the structured dialogue is implemented either through sentence openers or communicative acts (the term Scaffolding Sentence Templates (SST) is used for reference both to sentence openers and communicative acts). Each SST belongs to a specific discourse category (e.g. Proposal, Opinion). ACT supports an adaptation mechanism of the communication taking into account the expected learning outcomes of the activity and the collaboration model followed. More specifically, the adaptation is realized at two levels (i) at the level of proposing the form of dialogue and the SST type that are considered more appropriate, and (ii) at the level of providing the most suitable set of SST in case of structured dialogue (Gogoulou, Gouli & Grigoriadou, 2008). Moreover, ACT enables students to negotiate on the form of dialogue and the SST type they prefer to use. Also, during their communication, students have the possibility to define their own SST in case the available ones do not cover their needs (Gogoulou et al., 2008). The students' defined SST are part of their student model and become available each time they use the ACT tool.

The paper focuses on the self-regulation mechanism and presents an experimental study conducted in the context of a peer-assessment activity.

Framework for self-regulation in ACT

A new direction that has emerged recently is interaction analysis, which provides information directly to students to self assess their activity. Students need: (i) support on the awareness of their own individual or collaborative activity, and (ii) external assessment of their activity and their product (Dimitracopoulou et al., 2005). Supporting them on a metacognitive level could give them the means to self-regulate their own activity during a session or during forthcoming sessions. The interaction analysis and feedback provision process, designed and implemented in the context of ACT, (i) takes into account the collaborative learning setting followed (i.e. the expected learning outcomes and the model of collaboration followed), (ii) supports a framework for the diagnosis and the evaluation of students' collaborative behavior both at the cognitive and social level, (iii) provides feedback at awareness, metacognitive and guiding level, and (iv) gives expert the possibility to tailor various parameters with respect to the goals of the underlying setting. More specifically, a set of indicators have been developed:

- the *Participation Analysis Indicator*: provides statistical information at student and group level concerning the discourse categories (e.g. Proposal, Reason, Question) of the SST that student/group has used,
- the *Cognitive Skills Indicator*: gives an estimation of student's behavior, at student and group level, with respect to the expected learning outcomes of the activity and the role that the student has undertaken,
- the *Initiating the Discussion Indicator*: concerns student's attitude in initiating/stimulating the discussion by making proposals or expressing an opinion,
- the *Advancing the Discussion Indicator*: reflects student's behavior in advancing the discussion in terms of (a) answering to his/her interlocutor' s messages (*Requested Answer Indicator*), (b) elaborating further on his/her interlocutor's contribution (*Optional Answer to Others Indicator*) e.g. in case that his/her interlocutor expresses his/her agreement or makes an inference, the student may attempt to comment on this or ask a question, and (c) elaborating further on his/her own personal opinions or inferences (*Optional Elaboration to Learner's own view Indicator*),
- the *Further Elaboration on Interlocutors' view Indicator*: reflects that student not only acknowledges his/her interlocutor's point of view but also wants to stress and elaborate further on the point under discussion (e.g. s/he not only agrees but also argumentates on her/his agreement), and
- the *Promoting the Discussion Indicator*: shows student's collaboration behavior in participating in a creative discussion. The *Initiating the Discussion Indicator,* the *Advancing the Discussion Indicator and the Further Elaboration on Interlocutors' view Indicator* partially contribute to the *Promoting the Discussion Indicator* with respect to the corresponding weights assigned by the instructor reflecting the degree of importance of each indicator in the context of the specific learning activity.

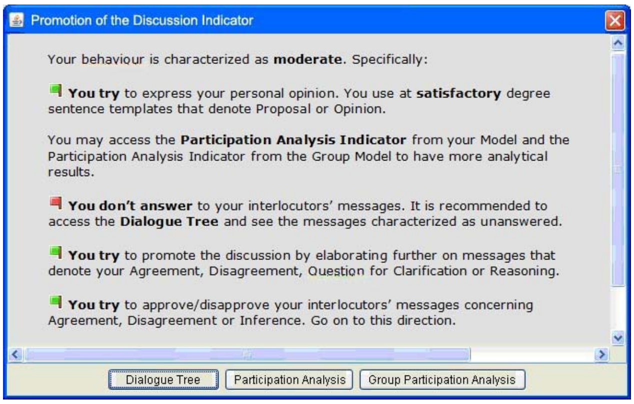

Figure 1. Feedback provided through the *Promoting the Discussion Indicator*; the first and the last two (green) flags denote satisfactory behavior while the second (red) flag denotes unsatisfactory behavior.

The feedback is provided at awareness, metacognitive and guiding level in textual and graphical form in order to (i) cover the diverse students' needs, abilities and preferences, and (ii) develop students' critical thinking, self-reflection and self-regulation abilities (Dimitracopoulou et al., 2005; Vosniadou, 2001) The provided feedback informs students about their behavior, explains how the system has reached the specific estimation and guides students appropriately by providing clues in improving their behavior. More specifically,

- at awareness level, the Participation Analysis Indicator, for student and group, is presented in graphical form.
- at metacognitive level, the *Cognitive Skills Indicator* at student level, the *Initiating the Discussion Indicator*, the *Advancing the Discussion Indicator*, the *Promoting the Discussion Indicator* (Figure 1) and the *Further Elaboration on Interlocutors' view Indicator* are presented in textual form aiming to inform student about

his/her behavior, explain the system's estimation and give hints for improvement. The *Cognitive Skills Indicator* at group level is presented in graphical form, enabling student to become aware of his/her behavior as well as of his/her interlocutor's behavior. Finally, the *Requested Answer Indicator* is presented in graphical form through the *Dialogue Tree* where the messages are presented according to their reference message and those messages considered as unanswered are annotated for each group member.

- at guiding level, the *Personal Guide*, tries to examine each member of the group in relation to his/her collaborators and gives guidelines both for the student under consideration and for his/her interlocutors in the direction of having a fruitful collaboration; it takes into account student's attitude in initiating the discussion and answering to his/her collaborators' messages as well as student's behavior with respect to the expected learning outcomes of the activity.

Experimental Study: Using ACT in peer-assessment activities

The ACT tool was used during the winter semester of the academic year 2006-2007 in order to support the synchronous communication of students while working out peer-assessment activities in the context of the undergraduate course "Didactics of Informatics" at the Department of Informatics and Telecommunications of the University of Athens. One of the primary objectives in the use of ACT was to examine the following two research questions: (i) What is the students' opinion about the self-regulation mechanism? Do they believe that the provided feedback can influence their behavior? (ii) Does the self-regulation mechanism affect students' behavior? What behavior patterns are detected?

Twenty four students (n=24: 12 groups of two students) participated in the study. Initially, the students answered a brief questionnaire aiming to elicit their experience in using chat tools and CSCL environments. Their answers revealed that they had little or no experience in using such environments. The students were randomly assigned to the experimental (n1=16: 8 groups of two students) and the control group (n2=8: 4 groups of two students); the control group was initially consisted of 12 students but four of them (2 groups) dropped out the lesson after the 3rd phase. The whole process was consisted of the following phases: (1) *1st phase: introduction to ACT tool* (1st week): The functionality of ACT was demonstrated to all students, (2) *2nd phase: familiarization with ACT* (2nd week): All students worked out several activities where they had the opportunity to use the sentence openers and the communicative acts and navigate in the available facilities, (3) *3rd phase: familiarization with the assessment process (3rd week)*: All students had to use the tool in dyads in order to work out an activity which asked them to define assessment criteria and evaluate a given lesson plan, (4) *4th phase: working out the peer-assessment activity (4th – 6th week)*: in *the authoring phase* of the peer-assessment activity, the students worked individually; each of the 24 students designed a lesson plan for a given subject and submitted it to the instructor via e-mail. In *the evaluation phase*, the students in dyads had to evaluate two anonymous lesson plans collaborating synchronously using the ACT tool. The students communicated in structured form using either sentence openers or communicative acts. 4 out of the 12 groups worked in distance while the rest 8 groups participated in a lab session for about 4 hours; each student in lab was working on his/her own computer communicating with his/her collaborator via ACT. The recorded dialogues were processed in order to delete any words indicating the evaluators' identity and sent back to the corresponding author in order to proceed to any improvements/changes following the evaluators' suggestions.

During the 3rd and 4th phase, the experimental group could access all the functionalities related to the self-regulation mechanism while the control group had no such facility available. At the end of the process, the experimental group had to answer to open and closed questions about the self-regulation mechanism (e.g. Do you think that the provision of the feedback information is useful? Do you understand the feedback?).

Qualitative and quantitative data were obtained and analyzed: (i) students' answers to the questionnaire, (ii) values of IA indicators, (iii) students' dialogues, and (iv) system log files recording students' actions.

Results

1st Research Question: What is the students' opinion about the self-regulation mechanism? Do they believe that the provided feedback can influence their behavior?

Regarding the first research question, students' answers to the questionnaire were analyzed. In particular, as far as the usefulness of the provided self-regulation facilities are concerned, the *Dialogue Tree* stands high in students' preference (92,3%) while at the lower position are the *Cognitive Skills Indicator* and the *Participation Analysis Indicator* (69,2%). Regarding the understandability of the provided feedback, students seem to have no problems (69,2% for the *Cognitive Skills Indicator*, 88,5% for the *Promoting the Discussion Indicator* and 84,6% for the *Personal Guide*). Also, students have positive view for the adequacy of the provided feedback, mentioning that it is not necessary to provide additional information. Regarding the content of the provided feedback, students consider particularly useful (92,3%) the explanation given for the discourse categories as they can understand how the system reached the specific estimation and the available clues about what they can do to improve their behavior. Considering the presentation form of the provided feedback, students are aligned with the supported forms (84,6% for the *Cognitive Skills Indicator*, 92,3% for the *Promoting the Discussion Indicator* and 92,3% for the *Personal Guide*). As far as their agreement to the system's estimation is concerned, the majority of them consider the estimations and the hints in the correct direction (61,5% for the *Cognitive Skills Indicator*, 65,4% for the *Promoting the Discussion Indicator* and 69,2% for the *Personal Guide*), commenting that the tool can estimate the intention of their contribution and not the real content – therefore some of them are quite cautious and rate the system's estimation as indifferent. Regarding their belief about whether the provided feedback influenced their behavior, students believe that they tried to take into account the feedback (57,7% of the students mentioned that the *Participation Analysis Indicator* influenced their behavior, 53,8% for the *Cognitive Skills Indicator*, 65,4% for the *Promoting the Discussion Indicator* and 57,7% for the *Personal Guide*). The analysis of students' answers revealed two trends as far as students' preferences about the provided feedback is concerned (i) there are students that prefer to have access to graphical form of feedback such as the *Dialogue Tree* and the *Participation Analysis Indicator*, and (ii) there are students that prefer to have at their disposal analytical information presented in textual form such as the *Cognitive Skills Indicator*, the *Promoting the Discussion Indicator* and the *Personal Guide*.

2nd Research Question: Does the self-regulation mechanism affect students' behavior? What behavior patterns are detected?

In order to investigate whether the provided feedback influences students' behavior, the values of all indicators were examined both for the experimental and the control group. The sum of the indicators' value per message for all members of each group was calculated. Also, the average value for the *Cognitive Skills Indicator* and the *Promoting the Discussion Indicator* was estimated. Figure 2 presents the *Cognitive Skills Indicator* while Figure 3 presents the *Promoting the Discussion Indicator*. The value of the *Cognitive Skills Indicator* for the experimental group is at a continuous progress and finally outweighs the control group. Regarding the *Promoting the Discussion Indicator*, both groups seem to improve their behavior with the experimental group to excel. Similar results stand for all the indicators, that is the values for the experimental group are on increase. From the above, it becomes apparent that the provided feedback influences students' behavior and has positive results in improving students' behavior and in having fruitful collaborations. The evolution of the indicators values is aligned with the students messages as these are recorded in the system's log files. The examination of students' dialogues and actions recorded in log files reveal that students tended to follow the provided hints and improve their behavior in most cases. Indicative examples that illustrate this attitude are presented in Table 1.

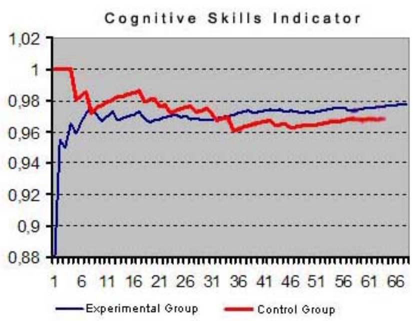

Figure 2. The evolution of the *Cognitive Skills Indicator* during message exchange.

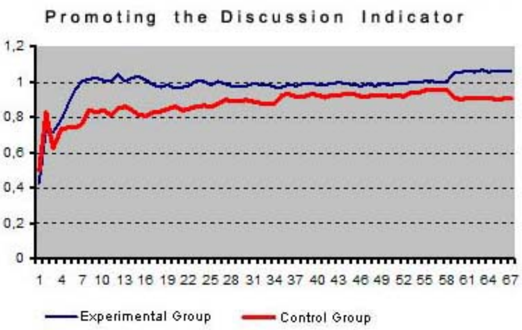

Figure 3. The evolution of the *Promoting the Discussion Indicator* during message exchange.

Table 1. Examples of dialogues and students' actions illustrating students' attitude to the provided feedback

Feedback	Student's reaction
The following feedback was given to one of the G2 group members: "*Try to express your personal opinion using sentence templates such as proposal or opinion. You should urge your interlocutors to do so. It is important that all group members participate actively in the dialogue.* *You should also answer to your interlocutors' messages. You can access the Dialogue Tree and see which messages you should answer.*"	The student answered to one of her interlocutor's message and then tried to encourage her interlocutor to express his opinion: *47. std0: Agreement [46/std1] : OK.* *48. std0: Question :Don't you think that the evaluation sheet is quite long?!?!?*
The following feedback was given to one of the G4	The student expressed his opinion after articulating his

group members through the Cognitive Skills Indicator: "*... you rarely use sentence templates that denote Proposal, Opinion, Reasoning or Explanation"*	agreement to his interlocutor's point of view: *28. std0: I agree with [27.std1]and I propose to mark this criterion with 10%.* *29. std0: I propose to go on to the next criterion. I believe that it should concern whether the lesson plan addresses all the predefined learning outcomes.*
The following feedback was given to one of the two G6 group members through the Promoting the Discussion Indicator*: "You don't try to express your opinion and initiate the discussion. You rarely use sentence templates such as Proposal and Opinion."*	The student expressed his agreement to his interlocutor's message and then tried to articulate his personal opinion: *10. std0: Agreement [9.std1] :Yes, I think it is OK.* *11. std0 : Opinion and Argument : For the third criterion, I think that the question is quite good and the use of the teaching method of lectures before ECLiP is good enough.*

Summarizing the results, the following patterns in students' behavior were detected:

- There are students that tend to activate all indicators, following the hints/advice of the current feedback. This category of students tended to access the *Personal Guide* at first place and then access the rest indicators following the given hints.
- There are students that show their preference to feedback (indicators) presented in graphical form such as *Dialogue Tree* and *Participation Analysis Indicator*.
- Some students activate very often the feedback functionalities trying to find out whether the system estimation changes as result to their behavior, while there are students that activate the specific functions only a couple of times during the dialogue.
- In general, students try to take into account the provided feedback especially in cases of unanswered messages or limited expression of personal opinion.

It is worthwhile mentioning, that the performance of the experimental group in the specific assignment (the average score was 7 in ten-scale) was higher than that of the control group (the average score was 5,8).

Conclusions and Future Plans

The use of ACT in the context of a peer-assessment activity showed that the supported self-regulation mechanism can help students in self-regulation and improved their collaboration behavior. The students seem to take into account the provided feedback and attempt to change their behavior. However, we believe that the use of ACT for longer periods of time is necessary in order to investigate how students behave and use the supported adaptation and self-regulation mechanisms in the context of various activities. Also, we plan to enhance the adaptive capabilities of the tool taking into account the interaction behavior of students and their preferences.

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The design of Peer Feedback and Reflection Tools in a CSCL Environment

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Abstract: This design study developed and tested a peer assessment tool and reflection tool for enhancing group functioning in a computer-supported collaborative learning environment. The underlying assumption was that group functioning can be positively influenced by making group members aware of how their behavior is perceived by themselves, their peers, and the group as a whole. This awareness, which is conditional for behavioral change, is achieved through a peer assessment tool and a reflection tool. A 2x2 factorial between-subjects design was used. Participants were 39 fourth-year high school students who worked in groups of 3 or 4 on a collaborative writing task. Results show that groups with peer assessment tool developed better teams, had lower levels of group conflicts, and had a more positive attitude towards collaborative problem solving, than groups without a peer assessment tool. Thus, peer feedback on social behavior of group members can enhance group functioning in CSCL-groups.

Introduction

Collaborative learning, often supported by computer networks (computer supported collaborative learning, CSCL) is enjoying considerable interest at all levels of education. Collaborative learning, defined as the "mutual engagement of participants in a coordinated effort to solve the problem together" (Rochelle & Teasley, 1995, p. 70) has, among other things, been found to enhance the learners' cognitive performance (Johnson & Johnson, 1999) and to stimulate them to engage in knowledge construction (Stahl, 2004). CSCL environments, though originally simple, text-based, computer mediated communication systems, have been strongly influenced by the rapid development of information and communication technology tools and widgets (e.g., e-mail, chat, video conferencing, and discussion forums). These applications have proven to be useful for supporting education and collaborative learning (Janssen, Erkens, Kanselaar, & Jaspers, 2007; Kreijns, Kirschner, & Jochems, 2003), leading to the design and implementation of more sophisticated CSCL environments.

Though CSCL environments have been shown to be promising educational tools and though expectations as to their value and effectiveness are high, groups learning in CSCL environments do not always reach their full potential. One of the most important reasons for this disparity between their potential and their results can be found in the social interaction between the group members, which is influenced by (1) the characteristics (i.e., the design) of the CSCL environment and/or (2) the cognitive and socio-emotional characteristics (behaviour) of the group members (Kreijns, Kirschner, & Jochems, 2003).

First, the design of CSCL environments is often solely functional, focussing on the cognitive processes needed to accomplish a task and/or solve a problem and achieving optimal learning performances (Kreijns & Kirschner, 2004). These functional CSCL environments force (coerce; Kirschner, Beers, Boshuizen, & Gijselaars, 2008) group members to solely carry out these cognitive processes and thus limit the possibility for socio-emotional processes to take place. These socio-emotional processes, which are the basis for group forming and group dynamics, are essential for developing strong social relationships, strong group cohesiveness, feelings of trust, and a sense of community among group members (i.e., for creating a sound social space). Without such a sound social space, the group will not reach its full potential (Jehng, 1997). Groups in CSCL environments that lack social functionalities will ultimately perform poorly (Cutler, 1996; Kreijns & Kirschner, 2004).

Second, group members can show non-cooperative behaviour (i.e., free-rider effect and sucker-effect), which can have negative effects on group functioning and group performance. The free-rider effect or hitchhiking effect occurs when group members think that their individual effort is unnecessary, because the task can be performed by the other group members. This often occurs when the individual group members receive a grade that is based on the performance of the whole group (Kerr, & Bruun, 1983). The sucker effect occurs when productive group members believe that they invest more time and effort in the group product than their co-members. The productive group members will often reduce their individual efforts, because they refuse to support the non-contributing members (Kerr & Bruun, 1983).

To this end, CSCL environments can be augmented with computer tools or widgets that support social functions. These tools, also known as 'social affordance devices', can positively effect group functioning and group performance in a CSCL environment (Kreijns & Kirschner, 2004). Social affordances are defined as those properties of the CSCL environment that act as social contextual facilitators relevant for the learner's social interaction (Kreijns, Kirschner & Jochems, 2003). Two types of social affordance devices are tools that (1) will make individual group members aware of how their behaviour is perceived by themselves, their peers, and the group as a whole (i.e., a tool that will give individual and team specific feedback on individual and group behaviour) and (2) will stimulate individual team members to reflect upon why they are thus perceived by the others (i.e., a tool that will stimulate them to think about and understand why others see them the way they do). This awareness, which is conditional for behavioural change, can be achieved through the implementation of a peer assessment tool, and the reflection through a reflection tool. The question that now arises is what the tools should precisely do and how they should be implemented.

Peer feedback

Peer feedback can be used to provide group members with information concerning their behaviour in a group (i.e., their interpersonal behaviour). This peer feedback can be focussed on evaluation and/or development. Topping (1998) has a more evaluative perspective on peer feedback and defines peer feedback as an "arrangement in which individuals consider the mount, level, value, worth, quality or success of the products or outcomes of learning of peers of similar status" (p. 250). In comparison, Earley, Northcraft, Lee, and Lituchy (1990) have a more developmental perspective on feedback which is focussed on performance improvement, and is described as information provided to an individual to increase performance. In this study, the developmental perspective on feedback will be used because the goal is to improve group functioning and group performance.

Group members can use peer feedback to monitor group processes or functioning (i.e., group processing). Group processing occurs when group members discuss how well their group is functioning and how group processes may be improved (Webb & Palincsar, 1996). These discussions may help groups pinpoint, comprehend, and solve collaboration problems (e.g., free riding, lurking) and may contribute to successful collaborative behaviour (Yager, Johnson, Johnson, & Snider, 1986). This is in line with McLeod and Liker (1992), who found that peer feedback on the interpersonal behaviour in a group can change the behaviour of individual group members. For example, giving group members peer feedback on their individual behaviour in the group (e.g., their degree of communication and collaboration), led to an increase in motivation, communication, cooperation, and satisfaction of all group members (Dominick, Reilly, & McGourty, 1997; Druskat & Wolff, 1999). However, there is still no empirical research that shows that peer feedback has a positive effect on group performance.

For this design study, a peer assessment tool was designed, developed and implemented in a CSCL environment to make individual group members aware of their own behaviour in the group, as well as the functioning of the group as a whole. This awareness, which is conditional for behavioural change, is achieved by providing the users anonymous information (feedback) on how their behaviour is perceived by themselves, their peers, and the group as a whole. This information will be gathered by use of peer assessment and will be based on specific traits because there is strong evidence that people form interpersonal perceptions by 'rating' other people on several traits (Brok, Brekelmans, & Wubbels, 2006). The peer assessment tool, therefore, consists of a self assessment and a peer assessment on five variables related to group functioning, namely: (1) influence; (2) friendliness; (3) cooperation; (4) reliability; and (5) productivity. These variables are based on studies on interpersonal perceptions, interaction, and group functioning (e.g., Bales, 1988; Brok, Brekelmans, & Wubbels, 2006; Kenny, 1994), and studies on group dynamics, group processes, and group effectiveness (Forsyth, 1999; Salas, Sims, & Burke, 2005). It is assumed that peer feedback in combination with reflection on individual behaviour and group functioning will be most effective (e.g., Schön, 1987).

Reflection

Reflection on group behaviour based on the information from the peer assessment tool can be seen as a feedback dialogue (Askew & Lodge, 2000). During a feedback dialogue, peers can discuss whether the feedback receiver understands the feedback, whether s/he accepts the feedback, whether s/he agrees with the feedback, whether the receiver is challenged to reflect on his/her own performance, and whether the feedback provides clues for behavioural change (Prins, Sluijsmans, Schreurs, & Kirschner, 2006). Thus, the peer assessment- and reflection tool will be used as a basis for stimulating and supporting peer feedback dialogues which can help groups to pinpoint, comprehend, solve collaboration problems, and may contribute to successful collaborative behaviour (Prins et al., 2006; Yager, Johnson, Johnson, & Snider, 1986). Bales (1988) concurs with this, arguing that open group discussions in which explicit decisions are made to modify behaviour can encourage transformation.

Research Goal

This design study is focussed on the design and implementation effects of a peer assessment tool and reflection tool, which in combination, can help a group to increase social interaction, group functioning, and group performance. The general goal of this study is to determine how and to what extent the peer assessment tool and/or the reflection tool affect social interaction, group functioning, and group performance within a computer supported learning environment. It is assumed that peer feedback in combination with reflection on individual behaviour and group functioning, will be most effective. The specific goal of this study is to determine whether the designed peer assessment tool and reflection tool are useful. Usefulness incorporates utility - the set of functionalities that a tool incorporates - and usability - whether a tool allows for the accomplishment of a set of tasks in an efficient and effective way, that satisfies the user (Kirschner, Strijbos, Kreijns & Beers, 2004).

Method

Participants

Participants were 39 fourth-year students (19 male, 20 female), with an average age of 16 (M = 15.54, SD = .60, Min =14, Max = 17), from an academic high school in The Netherlands. Students came from two classes and were enrolled in the second stage of the pre-university education track which encompasses the final three years of high school. The participants were randomly assigned by the researchers to groups of three or four, and to one of the four conditions (see Design). Group compositions were heterogeneous in ability and gender.

Design

A 2x2 between-subjects factorial design was used with the factors Radar unavailable (~Ra) – available (+Ra), and Reflector unavailable (~Rf) – available (+Rf). This leads to four conditions (~Ra~Rf, +Ra~Rf, ~Ra+Rf, +Ra+Rf). The condition with Radar and Reflector (+Ra+Rf) consisted of 11 students (2 groups of 4, and 1 group of 3), without Radar but with Reflector (~Ra+Rf) of 12 students (3 groups of 4), and with Radar but without Reflector (+Ra~Rf) and without both tools (~Ra~Rf) of 8 students (2 groups of 4).

Dependent variables

To measure changes in interaction between group members the communication between the group members saved in the data base (chat-history) is analysed. The dialogues between the group members is automatically coded by the Dialogue-act coding system (e.g., Erkens, Jaspers, Prangsma, & Kanselaar, 2005) which indicates the communicative function of an utterance (e.g., words, statements, expressions, et cetera) along five communicative functions (i.e., argumentative, responsive, informative, elicitative, and imperative).

The group functioning awareness scale for both peer feedback tool ($k = 4$, $\alpha = .83$) as reflection tool ($k = 2$, $\alpha = .61$), provides information about whether the tools were able to make group members aware of how their behavior is perceived by themselves, their peers, and the group as a whole.

The usefulness scale for both peer feedback tool ($k = 10$, $\alpha = .70$) as reflection tool ($k = 9$, $\alpha = .78$), provides information about whether the tools were considered as useful by the users.

The feedback dialogues scale for both peer feedback ($k = 2$, $\alpha = .69$) as reflection tool ($k = 2$, $\alpha = .66$), provides information about whether the tools stimulated dialogues on group functioning.

To measure group functioning, previously validated instruments were translated into Dutch and transformed into 5-point Likert scales (1 = totally disagree, 5 = totally agree). The Team Development scale ($k = 4$, $\alpha = .83$) provides information on the perceived level of group cohesion. The Group-process Satisfaction scale ($k = 4$, $\alpha = .83$) provides information on the perceived satisfaction with general group functioning (both cf. Strijbos, Martens, Jochems, & Broers, 2007); transformed into 5-point Likert scales). The Intra-group Conflicts scale ($k = 4$, $\alpha = .83$; cf. Strijbos et al.) provides information on the perceived level of conflict between group members. The Attitude towards Collaborative Problem Solving scale ($k = 4$, $\alpha = .83$; cf. Strijbos et al.) is self-evident.

The grade given to the groups' collaborative writing task (i.e., the essay) was used as a measure of Group performance. The essays were graded by two researchers, both experienced in grading essays. The inter-rater reliability was high ($n = 10$, Cronbach's $\alpha = .86$).

Task and procedure

The participating students collaborated in groups of three or four on a writing task in the history domain. Every student works at one computer. They had to write an essay about the film 'Fitna' by the Dutch parliamentarian Geert Wilders which argues that Islam encourages, among other things, acts of terrorism, anti-Semitism, sexism and violence against women, and Islamic universalism. This task was considered historically and civically highly relevant by the school. The collaborative writing task consisted two sessions of 90 minutes each, and the time between the first and the second session was one week. The groups collaborated in a CSCL environment called Virtual Collaborative Research Institute (VCRI; Jaspers, Broeken, & Erkens, 2002) which is a groupware program designed to support collaborative learning on research projects and inquiry tasks. VCRI will be further described in the Instruments section.

During collaboration, groups with a peer feedback tool, (+Ra~Rf, +Ra+Rf) made use of the tool at the beginning of the experiment (T1), halfway through the experiment which was at the end of the first session (T2), and at the end of the second and final session (T3). Note that the ‘time-on-task’ was the same for all four conditions. The groups with a reflection tool, (~Ra+Rf, +Ra+Rf), had to fill in the tool twice, namely halfway through the experiment (T2) and at the end of the final session (T3).

At the end of the final session (T3), the peer assessment- and reflection tool became available for all conditions so that all participants could assess their peers and reflect on their behaviours. Finally, all participants completed an evaluation questionnaire.

Instruments

Virtual Collaborative Research Institute (VCRI)

The Virtual Collaborative Research Institute (VCRI) is a groupware program that supports collaborative working and learning on research projects and inquiry tasks (Jaspers, Broeken, & Erkens, 2004). The VCRI contains more than 10 different tools, but only 6 were used for this experiment (see Figure 1).

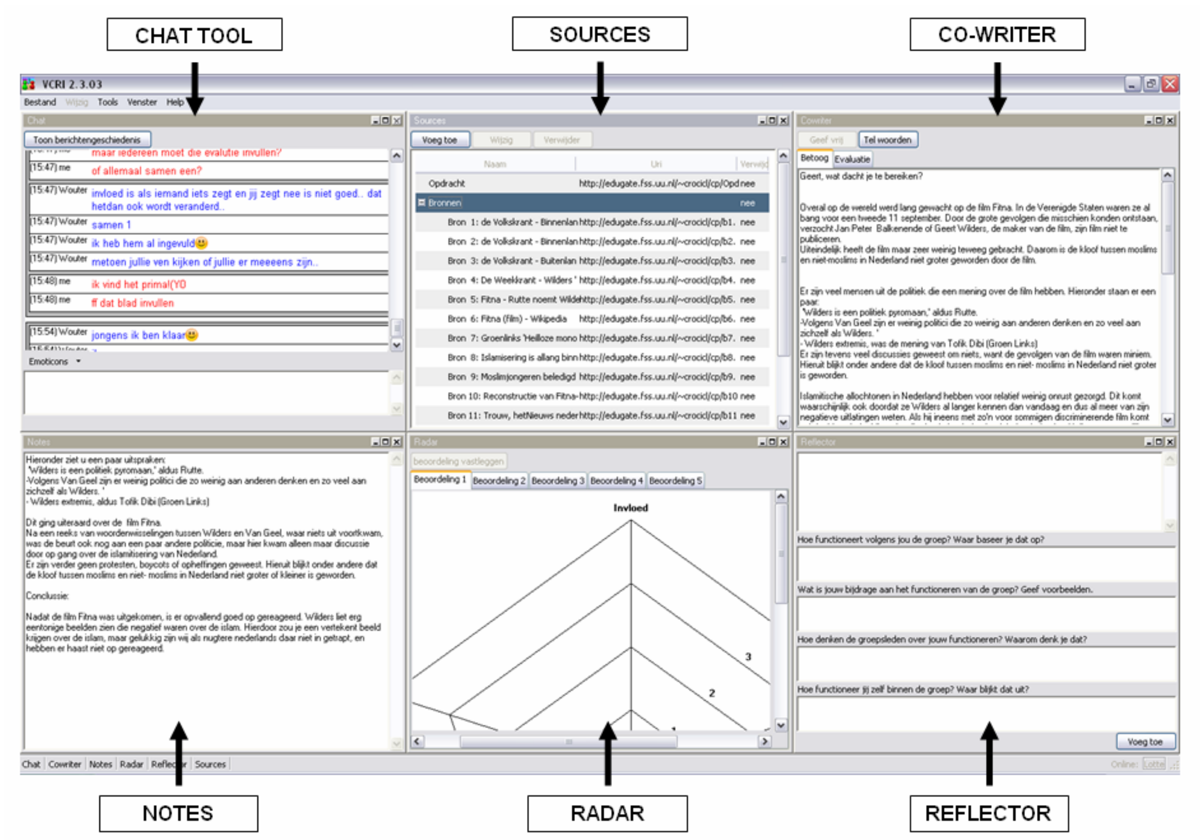

Figure 1. Screenshot of VCRI with the six tools used in this experiment.

The Chat tool (top left in Figure 1) is used for synchronous communication between group members. The chat history is automatically stored and can be re-read by participants at any time. Users can search for relevant historical information using the Sources tool (top center). The Co-Writer (top right) is a shared word-processor, which can be used to write a group text. Using the Co-Writer, students can simultaneously work on different parts of their texts. Notes (bottom left) is a note pad which allows the user to make notes and to copy and paste selected information. The Radar for peer assessment (bottom center) and Reflector for reflection (bottom right) will be described in the following sections.

Peer assessment tool (Radar)

VCRI was augmented with a peer assessment tool for stimulating and facilitating group-functioning awareness. This tool provided group members with information about their own behaviour towards the other group members, and the functioning of the group as a whole. Group members assessed themselves and their peers by rating several variables in an interactive radar diagram; named Radar.

The goal of this design-study was to develop a peer feedback tool that is easy to use and to interpret. A radar diagram is appropriate because it is capable of visualising the output of multiple persons on multiple variables. The radar diagram for self- and peer assessment consisted of five variables, namely: (1) influence; (2) friendliness; (3) cooperation; (4) reliability; and (5) productivity (see Figure 2). These variables are based on studies that focus on interpersonal perceptions, interaction, and group functioning (e.g., Bales, 1988; Brok, Brekelmans, & Wubbels, 2006; Kenny, 1994), and studies that focus on group dynamics, group processes, and group effectiveness (Forsyth, 1999; Salas, Sims, & Burke, 2005). These variables, as well as the reasons for their choice, are discussed in Phielix, Prins, and Kirschner (in preparation).

In the Radar, all group members are both assessor and assessee. In the role of assessor, the to-be-assessed peer in the group can be selected and her/his profile will appear as dotted lines in the centre circle of the radar diagram. Each group member is represented by a specific colour in the Radar. The assessor rates her/himself and all of the other group members on the five variables mentioned earlier, using a continuous scale ranging from 0 to 4 (0 = none, 1 = less, 2 = average, 3 = high, 4 = very high). The ratings are automatically saved in a database. To simplify data-analysis, the ratings are transformed to a scale from 0 to 100 by multiplying the ratings by 25. The assessment is anonymous; group members can see the output of the assessments of the other group members, but cannot see who entered the data.

After all group members have completed their self- and peer assessments, two modified radar diagrams become available on the screen. The first - Information about yourself - shows the output of the self assessment (e.g., Chris about Chris) along with the average scores of the peer assessments of her/him (e.g., Group about Chris). The self-assessment is not taken into account when the average scores are computed. To provide the students with more information about the variance in the average score their assessment by their peers, they can see the individual assessments of the other group members about their own behaviour (e.g., Group members about Chris). The second - Information about the group (see Figure 2) - represents the average scores of the group members, so that group members can get a general impression about the functioning of the group.

All group members are represented as a solid line in the diagram, each with a different colour. It is possible for the student to exclude data in the diagram. The student can decide which group member to include in or exclude from the diagram by clicking a name in the legend. It is also possible for group members to compare their self-assessments with the average scores of the assessments of their peers.

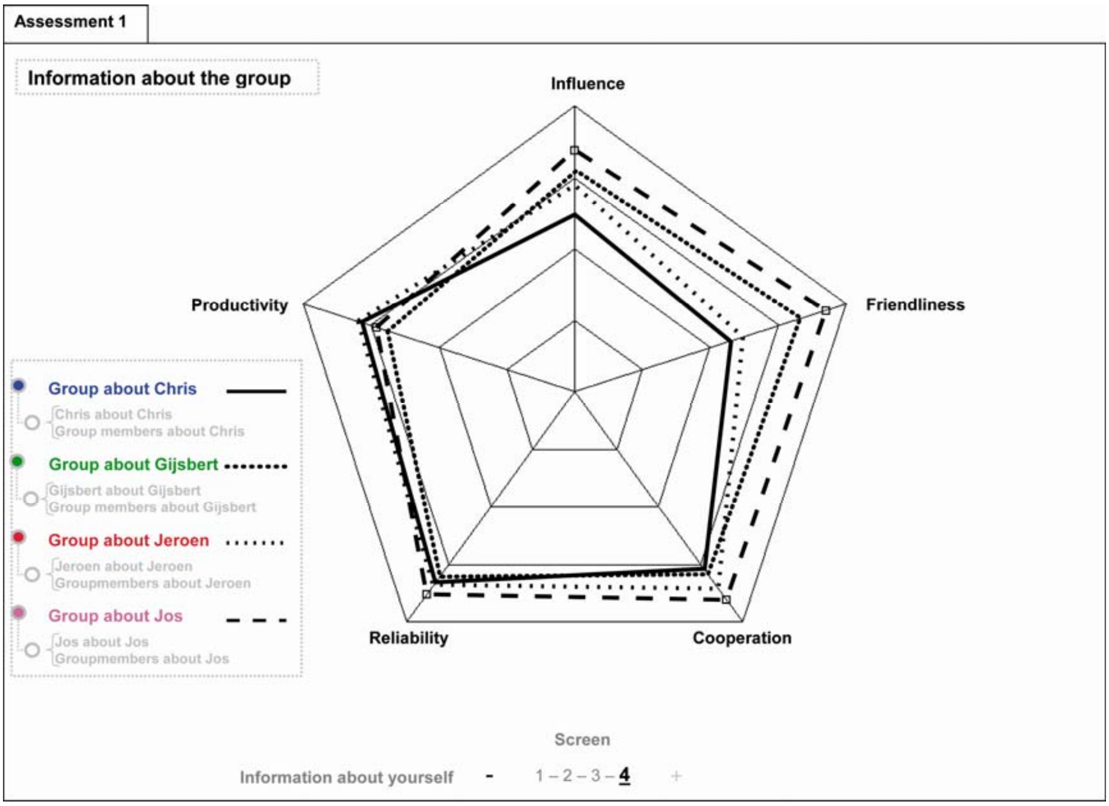

Figure 2. Output group assessment

Reflection tool (Reflector)

VCRI was also augmented with a reflection tool (Reflector) containing five reflective questions designed to stimulate reflection on different aspects of the group processes taking place. The questions were:

- What is your opinion on how the group functioned? Give arguments to support this.
- What do you contribute to the functioning of the group? Give examples.
- What do the other members of your group think about your functioning in the group? Why do you think

this?

- What is your opinion on how you functioned in the group? Give arguments to support this.
- What does the group think about its functioning in general? Discuss and formulate a conclusion that is shared by all the group members.

The first four questions are completed in the Reflector, and completion is indicated by clicking an 'Add'-button. This allows the student to share her/his answers with the rest of the group and allows her/him to see the answers of the others. Students can only gain access to the answers of their peers after they have added their own answers so as not to be influenced by one another. The fifth question is completed in Co-Writer which allows writing a 'shared' conclusion.

Results

Group Radar

Table 1 shows the means and standard deviations of the scales usefulness, group functioning awareness and feedback dialogues, concerning the Group Radar. For all the scales a 5-point Likert scale was used. The scale usefulness consisted of 10 items ($\alpha = .70$). Overall students are positive about the usefulness of the tool ($M = 3.53$, $SD = .51$, $N = 35$). According to the majority of the students the data entry is easy (69%), as well as the interpretation of the output was easy to understand (89%). A small majority (51%) of the students would like to have the Radar during on-line collaboration, and 74 % think that the Radar is useful.

Table 1: Means and Standard Deviations of the Scales Usefulness, Group Functioning Awareness and Feedback dialogues.

Scales	*N*	*M*	*SD*
Usefulness Radar	35	3.53	.51
Group functioning awareness Radar	35	3.48	.73
Feedback dialogues	35	3.21	.86

Students were positive about the achieved group functioning awareness ($k = 4$, $\alpha = .83$), by the Radar ($M = 3.48$, $SD = .73$, $N = 35$). Students stated that Radar provided them with information about their own functioning in the group, and that it stimulated them to reflect on their own functioning in the group. Students also stated that Radar provided them new information about the functioning of their group members and the group as a whole. The perceptions of whether Radar affected interaction was measured with a 5-point Likert scale ($k = 2$, $\alpha = .69$). Students using Radar stated that it stimulated dialogues on group functioning ($M = 3.21$, $SD = .86$, $N = 35$). However, an independent samples t-test showed no significant differences in percentage frequencies of the five types of utterances in the chat history, between groups with and without Radar.

To examine whether the Radar had any effect on group functioning during the collaboration process, the average ratings between the first, second and third peer assessments were compared. Table 2 shows the results of a paired samples *t*-test between the first, second, and third assessments, with influence, friendliness, cooperation, reliability and productivity as dependent variables. Self-assessments are excluded.

Table 2. Paired Samples t-test between Peer Assessments on T1, T2 and T3 (n=54).

	Paired differences between					
	assessment T1-T2		assessment T2-T3		assessment T1-T3	
	M	*SD*	*M*	*SD*	*M*	*SD*
Influence	3.15	14.45	-.82	9.93	2.33	11.61
Friendliness	6.02**	13.49	-5.26**	12.70	0.76	16.48
Cooperativeness	3.50*	12.10	-1.98	9.08	1.52	12.49
Reliability	5.01*	17.85	-5.77**	14.11	-0.76	13.18
Productivity	-2.23	12.03	-.33	13.03	-2.56	13.07

* $p < .05$ (2 tailed)
** $p < .01$ (2 tailed)

On average, all ratings on the second assessment decreased compared to the first assessment, except for productivity. Students perceived significantly less friendliness ($t = 3.28$; $df = 53$; $p < .01$), less cooperativeness ($t = 2.13$; $df = 53$; $p < .05$), and less reliability ($t = 2.07$; $df = 53$; $p < .05$) at the second assessment. On average, all ratings on the third assessment increased compared to the second assessment. Compared to the second assessment, students perceived significantly more friendliness (t = -3.04; df = 53; $p < .01$) and more reliability (t = -3.01; df = 53; $p < .01$) at the third assessment. The ratings of the third assessment increased towards the values of the first assessment. No significant differences in means were found between the first and third assessment.

The effect of Radar on group functioning was also measured using four 5-point Likert scales in the questionnaire that addressed team development, group satisfaction, level of intra group conflicts, and attitude towards problem solving. A two way between-groups ANOVA was conducted to explore the effect of Radar and Reflector on team development, group satisfaction, group conflicts and attitude towards collaborative problem solving. Participants were divided into four groups according to their condition. There were no significant interaction effects between Radar and Reflector, and no significant main effects for Reflector. There was a main effect for Radar on team development, $F(1, 30) = 4.19$, $p = .05$, with a medium effect size (partial eta squared = .12), level of group conflict, $F(1, 31) = 4.49$, $p = .04$, with a medium effect size (partial eta squared = .13), and attitude towards collaborative problem solving, $F(2, 31) = 1.44$, $p = .04$ (one-tailed), with a medium effect size (partial eta squared = .13).

An independent t-test was conducted to examine the main effects of Radar on team development, group conflict and attitude towards problem based collaboration. Conditions +Ra~Rf and +Ra+Rf were combined into a new group named 'with Radar', and conditions ~Ra+Rf and ~Ra~Rf were combined into group 'without Radar' (see Table 3).

Table 3. Independent Samples *t*-test Between Groups With and Without Radar.

Scale	Treatment	N	M	SD	Mean difference	p	η^2
Team development	with radar	16	4.08	.35	.26*	.04	.09
	without radar	18	3.82	.48			
Group satisfaction	with radar	17	3.95	.55	.00	.49	.00
	without radar	18	3.95	.70			
Level of group conflict	with radar	17	1.79	.37	-.38*	.03	.11
	without radar	18	2.17	.71			
Attitude towards collaborative problem solving	with radar	17	3.89	.39	.32*	.04	.09
	without radar	18	3.57	.62			

* p < .05 (1-tailed)

The results in Table 3 show that groups with Radar (+Ra~Rf and +Ra+Rf) scored significantly higher on team development, $t(32) = 1.79$, $p = .04$ (one tailed), experienced a significantly lower level of group conflicts $t(36) = -2.03$, $p = .03$ (one tailed), and had a significantly more positive attitude towards collaborative problem solving, $t(29) = 1.84$, $p = .04$ (one tailed), than groups without Radar (~Ra+Rf and ~Ra~Rf).

The five components of the Radar

Factor analysis was carried out to determine whether the Group Radar measured five independent components of group functioning. One component was found for groups without Radar, two components were found for groups with Radar. The first component consisted of the variables influence, friendliness and cooperativeness. The second component consisted of reliability and productivity. Additionally, correlations were calculated between the five variables that were envisioned as affected by the peer-assessment tool (see Table 4), and compared between groups with and without Radar. All variables at the final peer assessment (T3) for the groups without Radar correlated relatively strongly with each other. However, correlations were considerably lower in the groups with Radar (see Table 4). In comparison with the groups without Radar, 'Reliability' no longer significantly correlated with 'Influence', 'Friendliness' and 'Cooperativeness'. 'Reliability' only correlated significantly with 'Productivity' ($r = .55; p < .01; n = 54$).

Reflector

Table 5 shows the means and standard deviations of the scales usefulness, group functioning awareness and feedback dialogues for the Reflector. For all the scales a 5-point Likert scale was used. The usefulness of the Reflector was measured by a 5-point Likert scale ($k = 9$, $\alpha = .78$) in the questionnaire. A majority of the students (63%; n = 20) found that the questions in the Reflector were clear, but overall students were not very positive about the functionalities of the tool ($M = 2.86$, $SD = .54$, $N = 32$). The majority (91%) of the students stated that they do not need a tool as the Reflector during on-line collaboration.

Table 4. Intercorrelations between the Variables on Peer Assessment T3 for Groups With Radar (*n* = 54).

Variable	Influence	Friendliness	Cooperativeness	Reliability	Productivity
Influence	-	.58**	.47**	.25	.39**
Friendliness		-	.52**	.05	.29*
Cooperativeness			-	.06	.41**
Reliability				-	.55**
Productivity					-

** $p < .01$ (2 tailed)
* $p < .05$ (2 tailed)

Table 5. Means and Standard Deviations of the Scales Utility, Usability and Awareness

Scales	*N*	*M*	*SD*
Usefulness Reflector	32	2.86	.54
Group functioning awareness Reflector	32	2.91	.83
Feedback dialogues	32	2.72	.84

Students were not very positive about the achieved group functioning awareness ($k = 2$, $\alpha = .61$), by the Reflector ($M = 2.91$, SD = .83, N = 32). According to the students, the Reflector did not really stimulate them to reflect on their functioning in the group, or provided them new information about group functioning.
To examine the perceptions of whether the Reflector affected interaction between group members (i.e., amount of peer feedback dialogues concerning group functioning) a 5-point Likert scale was used ($k = 2$, $\alpha = .66$). Students were asked whether the Reflector stimulated dialogues on group functioning, but the majority responded negatively ($M = 2.72$, $SD = .907$, $N = 35$). Analysis of the chat history showed no significant differences in percentage frequencies of the five types of utterances, between groups with and without Reflector.

A two way between-groups ANOVA was conducted to explore the effect of Radar and Reflector on group cognitive performance, as measured by the grade given to their essays. There were no significant interaction effects between Radar and Reflector, and no significant main effects for Radar or Reflector.

At the time this paper was written the qualitative analyses of the chat history and output of the Reflector were still in progress.

Discussion & Conclusion

In this design study, the usefulness and effects of a peer assessment tool and a reflection tool were examined. A CSCL-environment was augmented with a peer-assessment tool named Radar, and a reflection tool, named Reflector. It was assumed that Radar, in combination with Reflector, would positively affect social interaction, group functioning, and group performance. Note that not all data is analysed, so no definitive conclusions can be derived on how and to what extend the Radar and/or Reflector affect social interaction, group functioning and group performance. Nevertheless, several conclusions can be derived from the preliminary results concerning the design and effects of the tools, and the used method.

First, the design and effects of the Radar. Results show that students perceived the tool as useful, easy to use, and easy to interpret. According to the students, the Radar increased group functioning awareness and stimulated dialogues on group functioning.
As expected, main effects were found for Radar on team development, group conflict, and attitude towards collaborative problem solving. However, no effects were found for group satisfaction and group performance (grade given for the essay).

Factor analysis showed that the Radar only measured two components of group functioning, instead of five. The first component consisted the variables ‘influence’, ‘friendliness’ and ‘cooperativeness’, the second component consisted ‘reliability’ and ‘productivity’. Additionally, correlations were calculated between these five variables, and compared between groups with and without Radar. All variables at the final peer assessment (T3) for the groups without Radar correlated relatively strongly with each other. However, correlations were considerably lower in the groups with Radar. In comparison with the groups without Radar, ‘Reliability’ no longer significantly correlated with ‘Influence’, ‘Friendliness’ and ‘Cooperativeness’. ‘Reliability’ only correlated significantly with 'Productivity'. These results indicate that three out of five variables (e.g., friendliness, cooperativeness and productivity) need to be replaced. Nevertheless,

It appears that halfway the collaboration process the Radar has an effect on the individual behaviour of the group members. The results of the groups with Radar show a significant decrease in mean, on three out of five variables, halfway the collaboration process. Students perceived their group as significantly less friendly, less cooperative, and less reliable, in comparison of the first assessment (T1). The data, however, does not allow for the analysis of whether these differences were caused by the presence of Radar or Reflector. Due to the design of this study, the control groups did not have an assessment at the halfway point or at the beginning of the experiment. An explanation for the decrease in means halfway the collaboration process, could be that Radar provides the group members a more realistic, and less positive view on group functioning. This would be in line with findings of Homma, Tajima and Hayashi (1995), and Stroebe, Diehl and Abakoumkin (1992), who found that group members intuitively estimate the quantity and quality of their group product and their personal contributions, and that these estimates are generally unrealistically positive, resulting in an illusion of group productivity.

Second, the design and effects of the Reflector. Based on the results of the questionnaire, students stated that the Reflector itself has no added value during on-line collaboration. However, qualitative analyses of the chat history and output of the Reflector are still in progress. Although the effects of this study are mainly ascribed to the Radar, it is still assumed that Radar in combination with Reflector will be most effective. An explanation for finding no significant main effects for the Reflector on social group performance could be that in this study the Reflector was focussed on past and present (and not on future) group functioning, which might have caused superficial reflections, lacking reflections on future group behavior. Therefore, in further studies the design of the Reflector will be changed and will also be focussed on future group functioning, that is, on stimulating group members to formulate plans and set goals for improving social and cognitive group performance. Research has shown that outcome feedback can increase individual and group performance, especially when it is combined with goal setting (Mento, Steel, & Karren, 1987; Neubert, 1998; Tubbs, 1986), and there is no reason to believe why this should be different for process feedback.

Third, the method design of this study. Several limitations of this study should be kept in mind. The statistical power of this study is rather low because of the relatively small sample size ($N = 39$). However, even with this small sample, significant main effects were found for Radar on team development, level of group conflict and attitude towards collaborative problem solving.

In this study Radar is both intervention as measurement tool for the dependent variables (e.g., Influence and Friendliness). Therefore, with the current design it was not possible to determine whether the decrease of self assessment and peer assessment scores halfway collaboration at T2, was caused by the Radar or Reflector, or whether this also occurred in the control group. Therefore, in future studies, an extra control group will be added in which the Radar will become available at T2.

It is possible that the effects of the Radar and Reflector can only be measured over a longer period of time. In this study, the time between the first and last assessment was one week. Therefore, a second design study will be carried out amongst 25 third-year university student, who will collaborate, over a period of five months, on their bachelorthesis.

In sum, results with Radar are promising. They show that social group functioning in CSCL environments, such as team development, level of group conflicts and attitude towards collaborative problem solving, can be enhanced by adding an easy to complete and easy to interpret peer feedback tool, such as Radar. For Reflector, it was argued that the focus of the Reflector's questions should be directed towards future group performance and goal setting.

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Working collaboratively in small groups supported by KnowCat System: incidence on self-regulated learning processes

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Abstract: The aim of this research study was to examine the development of higher students' self-regulated processes after their participation in a specific CSCL system called KnowCat. Twenty-six university students participated in a 6-month learning project. During this period KnowCat learning environment was used to support scaffolding process among students in small group collaborative work. In the research study students' scaffolding processes in the different small groups were analyzed qualitatively. The results obtained in this study showed small group interaction patterns appeared while their members were working together throughout the instructional process supported by KnowCat. These interaction patters were related with an increasing number of self-regulated processes, specially planning, asking for clarification and monitoring skills.

Introduction

Learning in CSCL environment requires a learner to regulate his or her learning in order to construct higher and deeper levels of knowledge; that is, to make decisions about what, how and how much to learn, how much time to spend on it, how to access others educational materials, whether he or she understands the material, how modify plans and strategies to learn better and when to increase effort (Azevedo et al. 2005).

Wine's(2001) model of self-regulated learning let to examine the complex interplay between learner characteristics (e.g., prior knowledge, prior collaborative experience), elements of computer-supported environments (e.g., knowledge organisation, matchmaking, condition of participation) and mediating self-regulatory processes (e.g., planning, strategy use, monitoring activities). One way to foster student self-regulation is through the use of various kinds of contextual aids and others' scaffolds which may include access to static educational resources or a peer tutor who provides adaptive scaffolding to support students' self regulated learning.

Examining the role of scaffolds in facilitating students' self-regulate learning has become a critical issue in bridging self and externally regulated learning supported by computers. The social environment is viewed as a resource for self-enhancing forethought, performance or volitional control and self-reflection. Expanding on these ideas, it is hypothesized that in networked collaborative learning environments with an appropriate CSCL pedagogical model there are self-regulated processes which can be stimulated by peers (Hurme & Järvelä, 2006). In recent collaborative design systems research, this notion of scaffolding has been generalized to refer to aspects based on software tools to assist learners in making progress on collaborative task solving. CSCL enables students to see online fellows' solutions and provide them with specific widgets for explicit assistance to improve on task and process solving or they can discuss online how to solve the task.

The research project presented in this paper falls within this line of work. Our aim was to develop and analyse a pedagogical hands-on activity for one regular course over a six-month project at the Universitat de Lleida (Spain), by using specific and innovative CSCL software called KnowCat (Alamán & Cobos, 1999; Cobos, 2003) designed for supporting collaborative learning processes. Specifically, this research focuses on the analysis of students' development of self-regulatory processes in the context of joint small-groups learning activities supported by CSCL-KnowCat in higher education.

More in detail, the purposes of the study were to investigate:

- What effect does the students' participation in the KnowCat instructional environment have on the development of self-regulated learning skills?
- Which similarities and differences are in the scaffolding processes provided by students of the different smalls groups while they are working collaboratively with KnowCat?

Description of the KnowCat system

KnowCat (acronym for "Knowledge Catalyser") is a fully consolidated and thoroughly tested and validated CSCL system which has been developed at Universidad Autónoma de Madrid (Spain) an in active use since 1998. The main aim of this system is to generate quality educational materials as the automatic result of student interactions with the materials, by catalysing the crystallisation of knowledge (Alamán and Cobos, 1999; Cobos, 2003). More specifically, the system is based on a mechanism called "Knowledge Crystallisation". This mechanism gives us evidence about which the best contributions are in the user opinion through their interaction with the system.

KnowCat enables us to build up community knowledge sites –or knowledge sites for short. They are accessed through a specific URL using a Web browser and they are known as "KnowCat sites" or KnowCat nodes. Each knowledge site is organised around several knowledge elements. Firstly, the knowledge tree, which is a hierarchical structure of topics, displays the organisation of the knowledge site in several topics. Secondly, each topic contains a set of mutually alternative documents that describe the topic. At any given time, all documents contained in the same topic compete with each other to be considered as the "best" description of the topic. This competitive environment is achieved by the Knowledge Crystallisation mechanism of the system, which is supported by virtual communities of users (see its details below). At any time, the author of a document can contribute with a new version of his/her document.

Thirdly, each document can receive annotations –or note, for short–. A note is a review about the information presented in a document. Each note has a type that determinates its purpose. We have the following note types: a) “clarification” note: this is useful to clarify some parts of the document; b) “support” note: this is useful to express agreement with the document; and c) “review” note: this is useful to make suggestions about adding, removing, or changing some parts of the document, or for making comments regarding it. Finally, each document can receive assessments. An assessment represents a “weight assertion” which can be used by the users in order to determinate how good (with a value from 1, minimum value, to 10, maximum value) a specific aspect (i.e. correctness, innovative, etc.) of a specific part of a document (i.e. introduction, references, etc.) is.

The user operations provided by KnowCat are the next ones: modifying the knowledge tree, adding a new document to a selected topic, accessing to a document, voting a document, adding an annotation and assessments to a document, displaying the content of a note and the content of assessments, adding a new version of a document, displaying the content of a new document version.

The Knowledge Crystallisation mechanism takes into account the user opinions about the documents and the evolution of the opinions received to determine what documents are socially acceptable, in which case they remain in the knowledge site, and which of those are found unsatisfactory, in which case they are removed from the knowledge site.

Whether or not a document is socially acceptable is determined by its “degree of acceptance” as calculated by the Knowledge Crystallisation mechanism. More specifically, the degree of acceptance of a document is formulated using the explicitly received opinions concerning the document: the received votes, how these votes were received, the received annotations and their respective types, and the received assessments and their values; and the implicitly received opinions regarding access to the document.

Moreover, we have taken into account in this mechanism the "quality" of the users. In other words, we prefer to give more credibility to opinions from experts than those from occasional users. KnowCat establishes categories of users through the same means as the scientific community establishes its member's credibility, that is, by taking into account past contributions. Therefore, this system deals with "virtual communities of experts".

KnowCat has been tested in several research studies with student communities at Universidad Autónoma de Madrid (Spain) and Universitat de Lleida (Spain). These studies and results are detailed in Alamán & Cobos (1999); Cobos (2003); Cobos & Pifarré (2008) and Diez & Cobos (2008).

Research Methodology

Our study took the form of a case study conducted in an authentic university class environment. The purpose was to follow the scaffolding processes among students working in small groups over a six-month learning project. The study was conceived as a field case study and the analysis was initially planned on a descriptive level. Nevertheless, as we were addressing to study the evolution of the development of self-regulated skills a long the learning project we analysed the changes in using self-regulate skills to solve two problem-based activities using the CSCL-KnowCat; one activity was solved at the beginning of the learning project and the second activity was solved at the end of the six-month learning project. We adopted a coding scheme which would allow quantitative results to be stated.

Participants

Twenty-six university students participated in the research. They used KnowCat during one term in the context of the university course “Psychopedagogy Intervention in children development disorders” of the Psychopedagogy degree. The course lasted for 12 weeks (4.5 hours per week).

The students were randomly distributed in six small groups to solve the two problem-based activities of the study. Each small group was composed of 4-5 students.

Intervention: Main pedagogical characteristics of the CSCL instructional context

In order to assist the students in the use of KnowCat to construct knowledge collaboratively, and more specifically the KnowCat notes as improved scaffolds that could help their classmates to improve their documents, we designed a specific educational process in which the pedagogical prerequisites pointed out in CSCL literature were introduced.

The collaborative KnowCat system was used in authentic problem based activities in which students had to design a pedagogical intervention to respond a real case. Students solved two-problem based activities with KnowCat. To solve the two problem-based activities, students work with the assistance of KnowCat at two collaborative levels: in small group level in phase 1, and group class level (all students formed this group class) in phase 2. The main aim of the students' work with KnowCat in the phase 1"working in small groups" was to elaborate a common pedagogical intervention report to respond a real educational case. The collaborative small group procedure characteristics in phase 1 were as follows:

a) Each student wrote an individual report containing the individual resolution of the real case and submitted it as a document in KnowCat.
b) The other members of the small group read all peer's report separately and annotated them –i.e. by giving assistance– in order to help a fellow classmate to improve it.
c) The document's author read the notes concerning his/her own report taking into account both the classmates' notes and documents, re-wrote his/her own document and submitted it to the system again as a new document version. When students re-wrote their document, they could introduce ideas included in clasmates' documents, because the objective of re-writing the document was to elaborate collaboratively the best group pedagogical intervention to the real case.
d) The members of each group vote the best report which contained the adequate respond to the real educational case. The document which was the most social accepted one (calculated by the KnowCat Knowledge Crytallisation mechanism) was submitted to the system in the "class section" as a group document, and shared it to the other groups of the class (see figure 2).

The aim of the students' work with KnowCat in the phase 2 "working with the whole group class" was to decide which small group document was the best educational intervention to respond each real case. The procedure was as follows:

a) Students read all the documents submitted by the six different small groups and voted for the best one. Students argued their reasons in the voting process.
b) KnowCat Knowledge Crytallisation mechanism was a great help in order to select which the social accepted document of the whole group class was.

Data Analyses

A coding scheme was used to study possible changes in the content of the notes and in the learning processes required for the writing of these notes during the solution of the two activities. The coding scheme was based on the categories developed by Veldhuis-Diermanse (2002). The scheme distinguishes three general types of learning activities (or categories) and nine subcategories: (1) cognitive activities –three subcategories are distinguished: debating ideas, using external information and experiences, and linking or repeating internal information; (2) metacognitive activities –three subcategories are distinguished: planning, keeping clarity and monitoring; (3) affective activities –three subcategories are distinguished: general reaction, asking for general feedback and chatting or social talk.

This paper pretend to study deeply the regulation of group processes aimed at stimulating collaborative learning, for this reason we will focus on a deeper analysis of the metacognitive categories. The definition of the three subcategories of metacognitive learning processes referred to the students' self and external regulation shaped during the annotation process and is presented next:

Planning, when students present or ask for an approach or procedure to carry out the task. This presentation is followed by an argumentation or illustration.

Keeping clarity, when students ask for an explanation, synthesis of information, clarification or illustration as a reaction to certain information of the document. They give an example and/or add a new point to specific information

Monitoring, when students monitor the original planning or aim. The students mention the work done by their classmates and propose how to improve on it. Either that, or when students reflect on their own actions or on certain contributions to the database.

The coding process consists of two steps: a) dividing the messages into meaningful units and, b) assigning a code to each unit. We decided to segment the notes into units of meaning by using semantic features such as ideas, argument chains, and discussion topics, or by regulative activities such as making a plan, asking for an explanation, or explaining unclear information. Validity and reliability aspects were considered in the study.

Results

In this section, we analyse the development of students' learning activities during their interaction with KnowCat. To reach this objective, we carried out a detailed study on the content of the notes written by the students during phase 1 "working in small groups" to solve collaboratively the two problem based activities. Figure 1 provides a general picture of the learning processes developed by the different small groups in solving the two problem-based activities -for example G1A1 represents the meaningful units contained in notes written by students of group 1 (G1) to solve activity 1 (A1).

The total number of notes and the meaningful units identified in these notes in the two activities are different; the number of meaningful units identified in the second activity is higher than the number of meaningful units identified in the first activity in all the groups.

Particularly interesting is the increasing in all the small groups the number of metacognitive meaningful units in the resolution of the second problem-based activity. In our research we emphasized the use of the KnowCat notes as improved scaffolds among peers in order to write collaboratively the best solution to the presented problem based activity, and therefore in studying the students' metacognitive learning activities, our main focus was analysing external regulative learning which can help students to run group processes, to make plans aimed at successfully carrying out the task, to monitor their learning processes and to assist each other for learning ends.

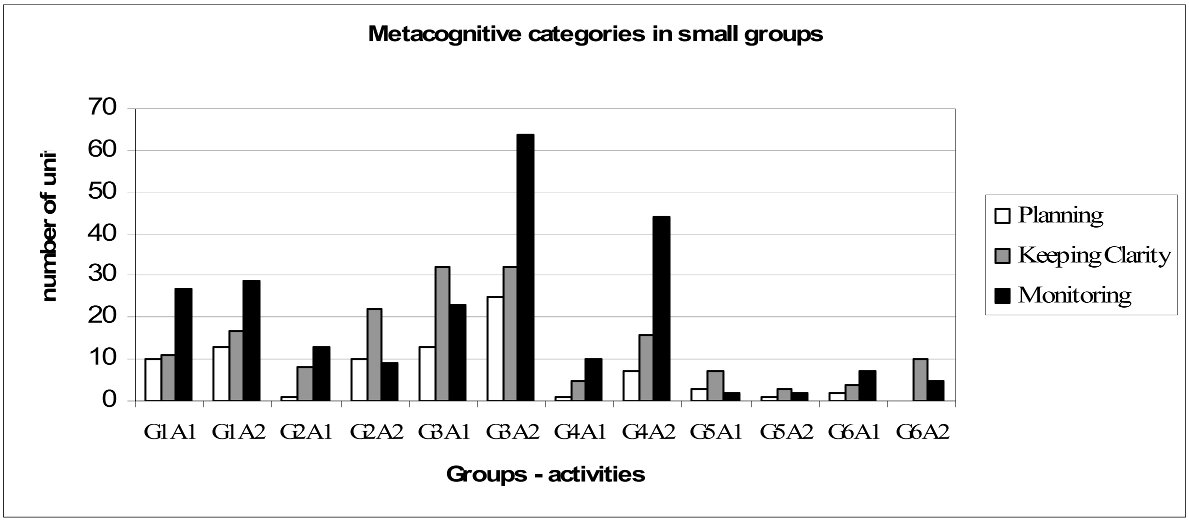

Figure 1. Distribution of the meaningful units identified by the different small groups (G1-G6) in the two activities (A1-A2) in the metacognitive categories.

The results obtained in our study show that students increase the presence of self-regulated processes while they were working in the CSCL-Knowcat environment. Students while regulate their own activity in the collaborative learning environment they were also able to monitor and control how their peers were working in the same task. From our point of view, these results give experimental data that KnowCat knowledge elements could support the development of external and self-regulated skills.

The increasing of the number of self-regulated processes in students' active participation in the networked learning –specially those processes referred to monitor and control other's work– is very challenging because educational research has shown that one benefit of students participation in CSCL environment is the fact it requires students to construct explanations which formulate their ideas or construct scaffolds which provide help to others during the collaborative task (Ploetzer, Dillenbourg, Preier & Traum, 1999).

Furthermore, the results of the current study illustrate how the students' participation in KnowCat instructional process might have an effect on the students' cognitive regulation particularly in planning actions (see figure 1). In the "Planning" category were coded meaning units where students asked for a new approach or procedure to carry out the task or where students presented or illustrated a new approach or procedure to perform the task and monitoring the learning processes. A growing body of research evidence demonstrates the positive effects of CSCL on self-regulated learning. CSCL sets demands and provides unique tools for engaging in specific self-regulation processes and the positive incidence of these processes in students' learning results (Koschmann, Hall & Miyake, 2001; Paris & Paris, 2001; Salovaara, 2005).

Conclusions

The instructional application of the KnowCat system could favour and improve the development of students' self-regulated skills. The results of the content analysis of our study highlighted that task resolution and networked discussions engaged students in specific self-regulation processes. Therefore, these results revealed that our study applied a good CSCL project to enhance the development of students' self-regulation skills and gave experimental data that the KnowCat system can assist students in the development of this cognitive self-regulation.

The results of our previous studies and the study presented in this paper have corroborated that KnowCat can support the construction of quality community knowledge and the learning processes among peer interaction.

It should be noted that the results of the current study are based on a reduced number of subjects and therefore, the emphasis of the study is on qualitative findings. However, the results of the current study illustrate how the students' participation in the CSCL-KnowCat instructional process might affect students' self-regulated skills.

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Effects of a context awareness tool on students' cognition of their team-mates learning time in a distance learning project activity

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Abstract: Aiming to understand and enhance metacognition in Computer Supported Collaborative Learning (CSCL), we considered time management as one of students' major challenges in CSCL. In collaborative activities, students need to know and regulate their individual and collective time being aware about their own and their team-mates expected availabilities. Aiming to understand and enhance time awareness in distance learning context we introduced a methodology for the assessment of Group Time Awareness, based on the comparison of subjective and inter-subjective students' learning time perceptions.
Assuming that enhancing awareness will help the collaborative learning process (McCarthy and Garavan, 2008) we hypothesize that group awareness could be improved by enhancing the reflexive properties of the Computer Learning Environment. For this purpose, we conducted an experimental study introducing a context-awareness tool in order to evaluate its impact on group time awareness scores.

Introduction and aims

Collaborative learning involves not only cognition about one's own cognition, resources and learning strategies (metacognition) but also the awareness of team-mate's cognition, resources and learning strategies. This second type of metacognition has been considered by some authors as metacognition in social context (Salonen, Vauras & Efklides, 2005), as inter-subjective awareness (Pata, 2008) but also, from the point of view of distributed cognition, as socially shared metacognition (Iiskala, Vauras & Lehtinen, 2004). We would adopt the perspective of cognition and metacognition as an individual process occurring on a social context; we consider cognition and metacognition as individual processes, although these could be influenced by the social context, or even more, these cognitive and metacognitive processes could concern the awareness of other individual's cognition and metacognition.

Aiming to understand and enhance metacognition in Computer Supported Collaborative Learning (CSCL) from a learner-centered approach (O'Sullivan, 2004), we considered one of students' major challenges in CSCL, the collective time management. Learning activities' time in CSCL could be scripted (Dillenbourg, 2002) at different levels of detail. Project oriented learning activities are low time-scripted activities, which allows the team to organize and regulate their work within the time limits of the project. Sometimes intermediate milestones or events could be introduced; however, the project oriented learning activity requires an important amount of time devoted to self-regulated learning at individual and collective level. Accordingly, learners need to manage their individual and collective time, and for that reason, students need to know and regulate their time being aware about their own and their team-mates availabilities. In order to improve learning time awareness in collaborative contexts we propose a methodology for the assessment of Group Time Awareness, based on the comparison of subjective and inter-subjective time perceptions.

Assuming that enhancing awareness will help team learning process (McCarthy & Garavan, 2008) we test the hypothesis that group awareness could be developed enhancing the reflexive properties of the Computer Learning Environment. For this purpose, we conducted an experimental study introducing a context awareness tool (Time Awareness Tool) in order to evaluate its impact on group time awareness scores.

Method

Context and participants

The course chosen for studying Group Time Awareness (GTA) is an introductory course in the first-year of the academic year for incoming new learners of Limoges University Virtual Campus (http://www-tic.unilim.fr). Choosing this first course, we avoid that the observed students had already developed their learning time habits in this context. The course, named UE153, is a 7-weeks course aiming to introduce the enrolled students (n=49) to Internet uses and functionalities during the first 4 weeks, in an individual learning modality. The last 3 weeks of the course propose the students to work on their first collaborative activity in the virtual campus.

At the beginning of the collaborative period, students were grouped into 6 teams. These virtual groups are composed by an average of 8.16 students (sd = 1.16). At the same time, each student was invited to declare the number of hours he uses to spend working and learning weekly.

Time support capabilities of the Computer Learning Environment

In order to organize their collaborative work, students need to know the prospective time of their team-mates. Without forcing students to explicit their time availabilities, this personal information will not arise spontaneously in an efficient way, making the group organization a difficult task, especially in distance learning groups, where time availabilities could not be inferred by the contextual information available simply by Computer Mediated Communication (CMC). In distance learning all contextual information is provided by the Computer Learning Environment (CLE), depending on two elements: Firstly, by the elicitations the students do during their CMC (an example in the case of contextual time information is the information provided when talking about their availabilities for a next chat meeting). Secondly, contextual information could be transmitted by the mirroring properties (Jermann, Soller & Muehlenbrock, 2001). Limoges University Virtual Campus is supported by Moodle Learning Managament System (Dougiamas, 2001). Moodle has been developed in order to support collaborative activities, but does not integrate a special support to enhance group awareness, nor special mirroring functionalities. Despite mirroring nor group awareness capabilities were not explicitly focused on its design and development, Moodle provides some contextual information that could help to develop the group time awareness during the collaborative activities. In real time, Moodle could display the online users list and interact with them through a chat channel or the instant message tool. Retrospectively, Moodle could display student participation information (last connection, activities logs, posted messages …). With this information, students could infer learning time patterns of their team-mates in an indirect way. On the other hand, we assume that part of the difficulty of collective time management in distance learning context is due to the lack of explicit group contextual information, as the mirroring (for current and past times) and foresight of team-mates presence and activity, which allows to build reliable temporal patterns that could enhances team's capacity to plan and regulate the collective learning times.

Materials

The declaration of individual learning time was supported by a context-awareness tool called Individual Time Awareness Tool (I-TAT).

TAT proposes two timescales, one for the week and another for the week-end, assuming that learning and work time patterns of the participants would be different in these periods. In this line, Andreu and Jáuregui (2005) observed that adult e-learners in self-regulated learning context spend more hours learning when their workload is lower.

Individual Time Awareness Tool (I-TAT) is primarily used as a time declaration tool.

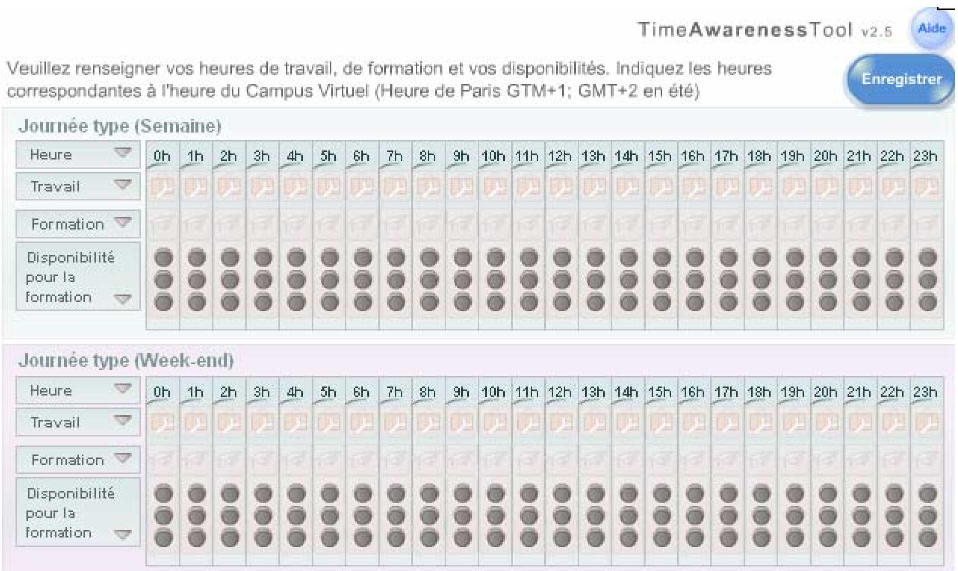

Figure 1. Students declare their work and learning times during the week and week-end in the Individual Time Awareness Tool (I-TAT)

Figure 2. Group Time Awareness Tool (G-TAT) provides a social shared visualization of each team-mate work and learning time

Learners can view the prospective time statements that he and his team-mates have declared. This estimate defines the hours they will dedicate to their job (monkey wrench icon) and the hours they intend to devote to their collaborative learning activity (graduation cap icon). The color gauges indicates, for each hour, if the student intend to dedicate it to the learning activity (green), if they could invest it if necessary, even if they didn't planned it initially (orange), or, if it's impossible to devote their time to the learning activity in any case (red).

Hypothesis

We hypothesize that the enhancement of the context information through a group awareness tool (the Time Awareness Tool) during distance computer supported collaborative activities will help to increase the group awareness and, specifically in our case, the Group Time Awareness (GTA). Aiming to test this hypothesis, we provide half of the groups (n=3) with the collective time functionality of the Group Time Awareness Tool (G-TAT), allowing them both to declare and modify their individual time, but, also, to have a group shared visualization of each team-mate work and learning time availabilities. We suppose this shared perspective will improve Group Time Awareness. The 3 other groups were considered as control groups, and have not received any specific help.

Procedure

The Group Time Awareness Tool (G-TAT) was introduced at the end of the first week of the collaborative activity to 3 groups of a total of 6 groups. The homogeneity of the groups according to their experimental or control condition was tested both in terms of group size (m=8.16; sd=1.16) and some usual demographic variables (family structure and children, work status). Any statistically significant was observed. After two weeks, at the end of the activity, students send their estimation about their team-mates learning time during the activity. Later on, the Group Time Awareness was calculated for each individual.

The measurement of the effect of the Group Time Awareness Tool (G-TAT) on Group Time Awareness (GTA) was conducted on an individual basis, where the answer of 18 students on the experimental group and 19 students on the control group was considered. To be considered, the student' answer should include his own learning time, even if his team-mates learning times estimation is incomplete. Group Time Awareness (GTA) score takes into account the number of estimates sent by the student. The more accurate estimates the students would realize, the better would be his GTA score. Some students (6 on the experimental group and 6 on the control group) didn't send their answers on the expected time (up to one week after the end of the collaborative activity) and were not forced to answer after this period. In addition to their team-mates' learning time estimate, some students sent spontaneously comments on their difficulty on estimating their team-mate's time engagement.

Measures

A week after the beginning of the collaborative activity, students were asked to send to their tutors the number of hours they spent on the group work since the beginning of the collaborative activity, and their subjective estimate of the number of hours invested by each of their team-mates, during the same period. From this data, was calculated the Group Time Awareness (GTA) for each individual.

Group Time Awareness (GTA) compares inter-subjective time awareness with the individual time declaration. GTA takes into account the individual student's perception on the number of hours per week his team-mates spent into the collaborative activity, which is compared to the number of hours per week declared by each team-mate. This comparison is operationalized through the mean of the standard deviations for each team-mate perception, divided by the number of team-mates perceptions sent by the student. Higher is the GTA score, the better is the awareness of other's team-mates learning times.

$$GTA = \frac{1}{(\frac{\bar{x}(\sigma)}{n})}$$

Results

A better Group Time Awareness was observed in the experimental group (m=1.31; sd=0.09) than in the control group (m=1.02; sd=0.09). Despite the higher GTA score in the experimental condition, this results is only slightly statistical significant. Having observed a non parametric distribution ion GTA scores, we conducted a U-Man Whitney test. As hypothesized, individuals having the Time Awareness Tool scored better than those which did not have it (U=106, p=0,049).

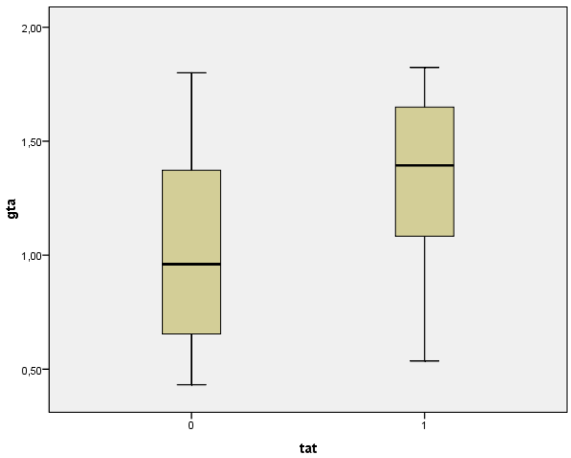

Figure 3. Group Time Awareness results distribution for students using the G-TAT (tat=1) or not (tat=0)

A closer observation of the data collected allows us to remark that students identify easily the team members who are not much involved or totally unengaged in the collaborative activity. Identification of inactive members occurs even for students who have a GTA score indicating a low perception of their team-mates learning time, or events, for students who have expressed spontaneously their difficulty in providing an estimate for the learning time spent by their team-mates.

We would also note an individual bias on the group learning time estimate. In general we observe that students who spent more time in the collaborative activity also estimate higher the time spent by their team-mates, a trend that is also observed in least invested learners, who tend to estimate the investment of their team-mates in a lower way, proportionally coherent with their own learning time.

Discussion: Time Awareness Tool influence on Group Time Awareness Index

A first limitation of this study is the low number of participants (n=49) and the high level of experimental mortality (12 participants did not send their team-mates learning time estimate). Further studies with larger samples are needed to verify the statistical significance of the group awareness improvements introduced by the Time Awareness Tool. Group size (m = 8.16, sd = 1.16) could had an influence in the collective time management and the group awareness evolution. It would be necessary to study the evolution of the Group Time Awareness (GTA) and the impact of G-TAT within different group sizes to consider the effect of the number of members of the group in the collective time management behavior, in general, and their GTA specifically.

The high level of experimental mortality is maybe a symptom of the poor usability or acceptability of G-TAT, or, at least, an indicator of the lack of the students' interest for collective time. G-TAT was not used by the student in the moment they were asked to declare the retrospective learning times of their team-mates. However, the quasi-experimental design we carried out didn't allow us to define the degree of influence of the use of G-TAT in the retrospective time estimations each student of the treatment group did. The impact of G-

TAT on short or long-term Group Time Awareness would need a deeper study to define the specific impact of this contextual awareness tool.

The contribution of this study could be considered on the suggested methodology for the assessment of students' cognition of their team-mates learning time during a collaborative activity. This methodology could be used in the field of peer evaluations and other collaborative learner-centered assessments. The second contribution could be considered at the level of the help tool (Time Awareness Tool) provided to the students in order to enhance their group awareness. The Time Awareness Tools was developed taking into account previous research in groupware and Human Computer Interaction, where some authors have already proposed contextual awareness tools aiming to improve the organization of working and learning groups (Ellis et al, 1990; Dourish & Belloti, 1992; Greenberg, 1996; Nova et al, 2003; Huang et al, 2008).

Further research will be conducted to better understand the effect of reflexive tools on the group time awareness, and understand the biases in the subjective perception of team-mates learning times that we observed in this study.

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Effects of Awareness Support on Moderating Multiple Parallel E-Discussions

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Abstract: Moderating multiple e-discussions at a time puts high demands on teachers as moderators. Therefore, to be able to provide effective moderation, teachers should be given adequate awareness support. We evaluated our e-moderation system called "Moderator's Interface" comparing moderation with and without awareness support. Following a within subject design, our cases were two teachers who were asked to moderate discussions of their students and to choose and prepare a discussion topic compliant with the curriculum. Results indicate that additional awareness support was deliberately used during moderation when available. An analysis of data from the teachers' answers to 120 questions and tasks indicates that in the awareness condition, both teachers performed better on the tasks as compared to moderating without awareness support. However, it could not be corroborated that teachers gained additional knowledge about the discussion solely from using the awareness support in absence of an external task.

Moderating E-Discussions

Research on supporting e-discussions has been a strong interest of the CSCL community (e.g. Kirschner, Buckingham Shum, & Carr, 2003). Existing e-discussion environments such as Belvedere (Suthers, 2003) and Digalo (Lotan-Kochan, 2006) offer a context in which learners can synchronously develop argumentation maps on a collaborative workspace. There has been a focus on facilitating learners' to engage in synchronous e-discussions, specifically investigating ways to provide guidance to the learner. For example Schwarz and Glassner (Schwarz & Glassner, 2007) found that floor control and providing specific ontological argumentation types can be beneficial to reduce superficial, chat-like discussions. While these efforts help to sustain autonomous discussions between peers, they do not take into account the role of the teacher in classroom-based e-discussions. Supporting the role of the teacher during e-discussions in classrooms has been taken up only recently (De Groot et al., 2007). Especially when it comes to synchronous e-discussions (and possibly multiple discussion spaces), teachers need to be supported to effectively moderate the students' flow of a discussion.

Problems of E-Moderation

Moderation during synchronous e-discussions puts high demands on a teacher. In a previous study on moderation investigating teachers' moderation styles and strategies, we found that teachers have difficulties to moderate effectively. For example, results indicated that teachers rarely encouraged students to formulate arguments or pose scaffolding questions but rather gave feedback only with respect to the process and social level (Wichmann, Harrer, & Hoppe, 2007). According to Chi and colleagues (Chi, Siler, Jeoug, Yamauchi, & Hausmann, 2001) only scaffolding questions and informative feedback is beneficial and has a positive effect on students' knowledge construction behavior. Interventions such as scaffolding questions and informative feedback require the teacher to evaluate the students' actions in terms of content, process, and social behavior. On a content level, a teacher needs to be able to grasp the focus of a student's contribution and monitor the content focus of the overall discussion. On a process level, teachers need to understand whether students engage in a critical style of argumentation. For instance, a student, who only contributes using affirming arguments, might need to be encouraged to critically reflect specific aspects in the discussion. Social behavior needs to be in focus of the teacher's attention to intervene on time when for example a student stops contributing. While engaging in effective moderation turns out to be to be a general problem for teachers during discussions, a specific challenge derives from moderating multiple e-discussions at the same time. Concurrent moderation of multiple discussions requires the moderator to switch between discussions and to perform several tasks at once.

A prerequisite for effective moderation (in form of posing scaffolding questions etc.) is the teachers' understanding of the students' activities during e-discussions. Especially when it comes to moderating multiple parallel discussions, teachers need to be supported handle the vast amount of information and to enable them to moderate a discussion effectively. The present research endeavor focuses on supporting teachers during moderations in terms of awareness support.

Awareness Support during Moderation

Awareness can be characterized as the understanding of the activities of others, which provides a context for one's own activity (Dourish & Bellotti, 1992). During the moderation of multiple parallel e-discussions, we believe that gaining awareness (an understanding of students' activities) needs to be supported. Awareness information needs to be provided in terms of: a) content awareness b) process awareness and c) social awareness (De Groot et al., 2007). This awareness support is expected to enable teachers to effectively carry out tasks. On a content level, it should enable teachers to provide informative feedback to the students. On a process level, awareness support should provide a teacher with information on how far a discussion has advanced with respect to a planned workflow. With regard to social aspects, awareness support should help a teacher to identify strong and weak collaborators instantly. A general problem (Manuele, Valdeni de Lima, & Marcos, 2003) of providing additional information often results in the opposite effect: Instead of enabling a user to make deliberate choices, the additional information leads to a mental overload and hence to ineffective or no use at all. Therefore, awareness information needs to be pre-selected and smoothly integrated with the environment.

The ARGUNAUT Approach

The goal of the EC-funded ARGUNAUT project (IST-2005027728) was to provide a moderation component called "Moderator's Interface", which enables teachers to moderate multiple parallel e-discussions. The Moderator's Interface allows the teacher to observe the development of the discussions via a Discussion Graph display. In addition, it offers awareness support and a remote intervention mechanism. Awareness support displays characteristics of a discussion in terms of content, process, and social aspects. Aspects related to content of students' contributions is represented in a Contribution Sequence display consisting (see Table 1) of a chat-like table. Process-related aspects are represented in the User Activity display and the Ontology display. The User Activity display shows number and type (e.g. new contribution, new relation etc.) of contributions by each student. The Ontology display shows number of pro – arguments and counterarguments as well as contribution type (e.g. argument, question, comment etc.) per discussion space. Social behavior is represented in the display called user relations. This display offers a visualization of collaborative activity per student using a social network diagram, which visualizes the level of interaction between users.

Table 1: Types of awareness support

Awareness Information about:	**Content**	**Process**	**Social Behavior**
Moderator's Interface Awareness Support:	Contribution Sequence	User Activity, Ontology	User relations
		Mini View	

Awareness displays are provided for every discussion space. A teacher can switch between existing discussion spaces and can view awareness displays and discussion graph display accordingly. Correspondingly, a teacher can send remote interventions (see Figure 1) in form of pop-ups and annotations using the Intervention Panel to every student individually or cumulative to all students of a discussion space.

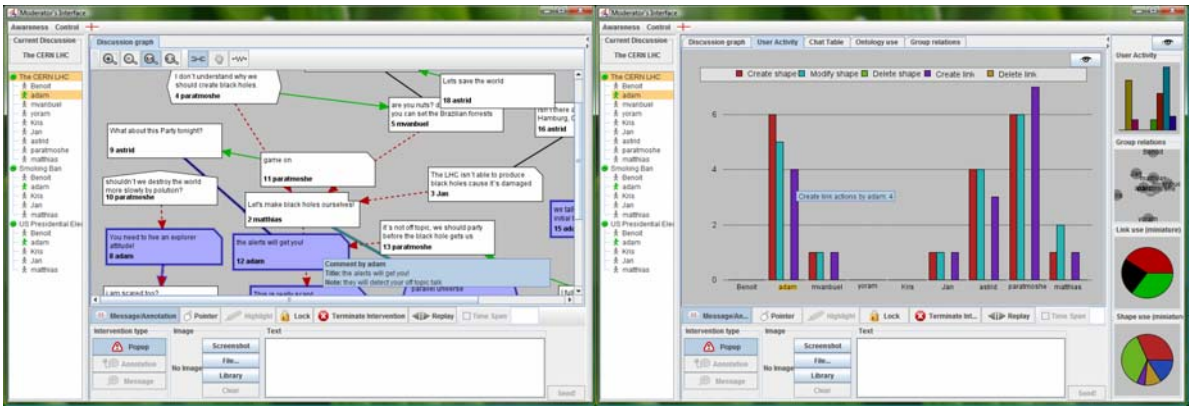

Figure 1. Moderator's Interface with Discussion Graph display only and Discussion Graph display + Awareness Support

Assumptions and Questions

The focus of this study is on the additional value of awareness support for teachers while moderating multiple parallel discussion spaces. We investigate whether teachers benefit from additional awareness support or not (see Figure 1). Specifically we expect that teachers will use the awareness support displays deliberately. However, it is an open question whether teachers gain more understanding through the deliberate use of awareness support. In addition, we assert that additional awareness support will lead to better task performance.

Method

Participants

Two teachers (teacher A and B) from two secondary schools in Germany served as cases for the study. Their respective school classes took part in the study. 24 students participated in the study the first day (class A) and 21 students participated the second day (class B). The students were between 15 and 16 years old. Class A was taught by a male teacher, instructing economy as a school subject. Class B was instructed by a female teacher within the subject of computer science. A teachers judgement on the students level of activity (1=very active, 2=average active, 3= not active) in the classroom was used for balancing purposes to assign each student randomly to one of the two conditions.

Design

The study followed a within subject design (see Table 2) regarding the teachers who worked as moderators in this study. In the *Awareness condition*, the teacher moderated the discussions using all components of the Moderator's Interface including the Discussion Graph display and the other awareness displays. In the control condition (*No Awareness condition*), the moderator could only access the Discussion Graph display, hence no awareness displays were available. The conditions were counterbalanced for avoiding sequence effects. That means, on the first day, teacher A moderated first in the *No Awareness condition* and afterwards in the *Awareness condition*. For Teacher B, moderating on the second day, we reversed this sequence.

Table 2: Within subject study design

Teacher A + class A(Day 1)	Teacher B + class B(Day 2)
No Awareness Condition (Moderator's Interface incl. Discussion Graph only)	Awareness Condition (Moderator's Interface Incl. Discussion Graph + Awareness Support)
Awareness Condition (Moderator's Interface Incl. Discussion Graph + Awareness Support)	No Awareness Condition (Moderator's Interface Incl. Discussion Graph only)

Procedure

The study took place in a university computer lab room. Each one of the two school classes visited the university for one school day to perform a discussion. The discussion topics were chosen and developed by the teacher and part of the curriculum. The teachers prepared the topic of the discussion sessions with lessons prior the study. For the class A the teacher discussed an economy subject related to an activity that has been planned and organized within the school year. The class B teacher decided to discuss the topic of privacy in the context of internet. On both study days, half of a class participated in the first condition. Before starting the discussions, we demonstrated the software FreeStyler (Hoppe & Gaßner, 2002). FreeStyler is a collaborative modelling environment, which offers various visual languages with handwriting support to engage in rich scenarios. For the purpose of this study, students participated in Freestyler discussion spaces to collaboratively develop argumentation maps. Students could choose various contribution types (e.g. Argument, Comment etc.) and related them to contributions of themselves or others using supporting or disputing links. Students spent 15 minutes trialling the software. After that, the students participated for about 50 minutes in the discussion. On both days, the first half of the class participated in the first condition (see Table 2), distributed in one of three FreeStyler discussion spaces (see Figure 2) while the second half of the class did other non-related activities. For the second condition, the second half of the class participated in the study while the first half did not. The moderation consisted of two moderation phases, an unguided moderation phase and a guided moderation phase. In the unguided moderation phase the teacher was being left alone with the moderation task. In the guided moderation phase, a research assistant asked questions.

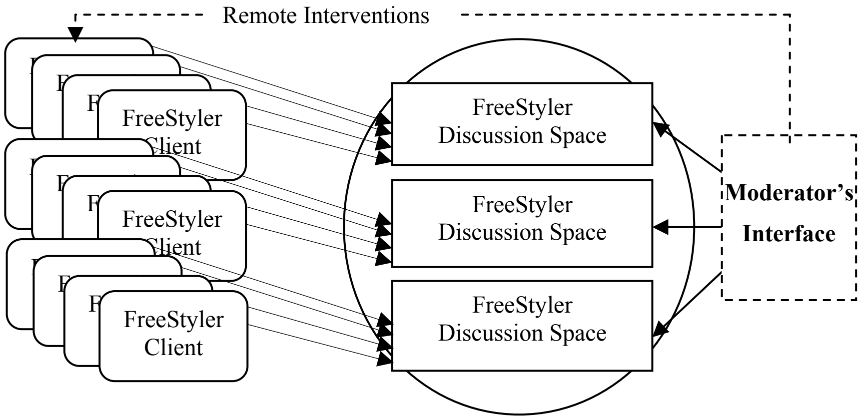

Figure 2. Freestyler discussion Spaces

Data sources

The research questions were evaluated with regard to teachers' knowledge and task performance. We measured the teacher's knowledge by asking 10 questions about the discussion state, during and after the moderation. For example, one question was: "Who is the strongest collaborator in the discussion?"Other questions were for example concerned with the number of links made by a specific person: e.g. "How many links were established by student X?" Every question could be answered using the Discussion Graph Display only, in other words, the questions were not tailored to aspects, which were only displayed in the awareness displays. Every question was asked for each of the 3 discussion spaces in one condition respectively. We measured teacher's task performance by prompting the teacher after each question to find (or confirm) the answer by using the Moderator's Interface. In each condition (Awareness condition and No Awareness condition), every question was read twice (one time to assess knowledge and one time to assess task performance) to the teacher and in addition provided on a paper. 120 answers (60 for knowledge and 60 for task performance) per teacher were written down, audio recorded and the teachers' actions were logged. We used a dichotomous coding to determine whether answers were correct (2 points) or incorrect (1 point).

Results

One hundred and twenty answers per teacher were first averaged across the 3 discussion spaces for every question and task respectively. Then means for all questions and tasks were in turn averaged separately again to have final mean scores for knowledge gain and task performance in both conditions respectively. Deliberate use of awareness displays: We analyzed the teachers' moderation behaviour in the *Awareness Support* condition in both phases the unguided moderation phase find out whether, the awareness support was used deliberately (instead of sticking to using the Discussion Graph only). Both teachers used all awareness displays available in addition to the Discussion Graph display. Most favoured displays were the Contribution Sequence Table display and the User Activity display.

Knowledge gain: Comparing the knowledge gain between the *Awareness Support* Condition and the *No Awareness Support* Condition indicated no differences. In both conditions, the moderators were not able to answer most of the questions correctly. Only one question was answered correctly in both conditions by both moderators ("Did everyone contribute?"). In addition, both teachers could identify correctly the strongest collaborator in almost all spaces (one teacher guessed incorrectly in one space). For all other questions, the moderators provided either no or an incorrect answer.

Task Performance: Results show that teachers in the *Awareness Support* condition, could perform all required tasks successfully (see Table 3). However, in the *No Awareness Support* condition, several tasks were not conducted at all or incorrectly. Especially tasks that cannot be answered through first glance at the Discussion Graph display have been conducted not at all or incorrectly if awareness support was not available. For example, in the *Awareness Support* condition, the teachers could easily determine strong collaborators, which they were not able to determine in the *No Awareness* Condition. With awareness support available, the teachers used the awareness display "User Relations" to determine the answer successfully. In most cases, both teachers used the same awareness displays to perform a requested task. Two tasks were performed using different displays: When tasks were concerned with determining the number of links made by a specific person, teachers used either the User Activity display or User Relations display.

Table 3.Tasks determined successfully

	Teacher A	Teacher B
Tasks without Awareness Support	1.36	1.69
Tasks with Awareness Support	2.00	2.00

Summary and Discussion

The results indicate that teachers took advantage of awareness support provided during the moderation of multiple e-discussions. Moreover, we found that awareness support was not only helpful but also necessary to complete the tasks successfully, since these required deeper insight into the argumentation maps. However, teachers did not gain more knowledge from using awareness displays alone. Rather, making use of awareness support by carrying out specific tasks resulted in better task performance and thus in better understanding of the students' activities. Gaining understanding during moderation is important because it is necessary for providing appropriate feedback to students.

A particular problem that arises from moderating multiple discussions is giving on time feedback. Even if feedback entails scaffolding questions as suggested by Chi et al. (2001), this information will only be helpful when provided within the respective situation. Interventions such as feedback that are provided out of context will rather be confusing than supportive to students. During moderation without awareness support, teachers spent a lot of time searching the Discussion Graph display to gain understanding of the students' activities. In the awareness support condition, the teacher avoided long searches by identifying relevant information using appropriate awareness displays.

Although our study consisted of only two cases, we collected 240 items. The items included 10 questions regarding understanding and 10 tasks, which have been measured repeatedly with 3 discussion groups in two conditions. In this sense, our N is small but still we have a reasonable collection of data to ensure reliability while assessing the added value of awareness support. One aim of this study was to evaluate the moderation component Moderator's Interface within the context of classroom lessons. Therefore, we accepted our small sample in favor of evaluating the software within a real classroom context. Research towards developing e-moderation software is a new field in the CSCL community. Future exploration on moderating e-discussions is needed.

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V.S.P.O.W.: An Innovative Collaborative Writing Approach to Improve Chinese as L2 Pupils' Linguistic Skills

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Abstract: This paper outlines an eclectic approach to assist juvenile Chinese as second language (L2) pupils in Singapore in developing linguistic-related micro-skills for writing. The recursive, bottom-up writing process requires the pupils to collaboratively carry out “word/phrase pooling”, “sentence making”, “paragraph writing” and “outlining” on wiki, and eventually composing their essays individually. The intention is to fill up the gap between the current-traditional product-oriented approach and the more cognitively demanding process-oriented approach, that is, juvenile L2 learners' limited linguistic and cognitive skills that would hinder them from writing proper essays, not to mention carrying out process writing. The results of our pilot study show that the target pupils' micro-skills for writing were improved significantly due to emergent peer coaching. There is also an implication that through such peer coaching activities, the perceived challenge of pupils' individual differences in linguistic proficiency could be turned into an advantage for motivating pupils' collaboration in learning.

Introduction

To typical ethnic Chinese students in Singapore, their lack of motivation and limited basic linguistic capability continue to be the fundamental challenges to their essay writing in Chinese Language (Sim, 2005). One major factor is the educational reform took place in 1984 when Chinese Language was reduced to an isolated second language (L2) subject in the primary and secondary schools. Furthermore, according to the studies, the proportion of Chinese Singaporean students entering Primary 1 who speak predominantly English at home has risen from 36% in 1994 to 51% in 2005 (People’s Daily Online, 2005). Singapore students who are educated in such an education system that favors English Language since they are young find it a challenge to learn Chinese, especially in acquiring the writing skills (Liang, 2000).

In this paper, we report on a researcher-teacher Collaborative Inquiry (Darling-Hammond, 1996) project in designing and piloting a wiki-based collaborative Chinese essay writing approach that aims for addressing typical linguistic weaknesses of primary school pupils in writing. The novel collaborative writing approach can be characterized as a recursive, bottom-up process that requires the pupils to collaboratively carry out “word/phrase pooling” (vocabulary), “sentence making”, “paragraph writing” and “outlining” on their group wiki pages; and eventually composing their essays individually (“essay writing”) with word processor. We name the process as “V.S.P.O.W.” (Vocabulary, Sentence, Paragraph, Outlines, [essay] Writing).

This paper focuses on a conceptual analysis on the design of V.S.P.O.W. which is backed by the preliminary findings of a pilot study conducted at a Primary 4 (10-year-old) mother tongue (Chinese L2) class in a neighborhood school in Singapore. In addition, we are looking into the potential of the approach in addressing and even tapping on pupils' individual differences through teacher or student-initiated customization of the writing process and emergent peer coaching to improve the pupils' micro-skills for writing and attitudes toward Chinese learning and writing.

Literature Review

L2 writing instructions: from product-oriented pedagogy to process writing

Writing is arguably the most complex skill in language learning. Traditional rhetoric writing pedagogy mostly focuses on writing product (He, 2005). In general, the purpose of a composition task in such an approach is not to express ideas or develop critical thinking, but to practice words, phrases, and sentence structures in the target language. As Silva (1990) and Ferris & Hedgcock (1998) stated, in early L2 writing instruction, a writing task was the “controlled composition” designed to “give student practice with particular syntactic patterns and/or lexical forms.”

Process pedagogy arose in the late 1960s in reaction to the dominance of product-centered pedagogy (Matsuda, 2003). Methodologies for writing instructions began to move from a focus on product to emphasis on the process. “Process writing” refers to as a writing instruction that views writing as an ongoing process in which students follow a given set of procedures for planning, drafting, revising, editing, and publishing their writing (NDE, n.d.). Furthermore, it places a greater interest in peer reviews, audience, purpose, and author's voice (Williams, 2005, p.35).

Although process writing was touted "the most successful (approach) in the history of pedagogical reform in the teaching of writing" (Matsuda, 2003), it is not without limitations. Originally developed for L1 students, early descriptions of process writing advocated teaching cognitive strategies used by expert writers to novices (e.g., Flower & Hayes, 1977; Flower, 1979). Indeed, there were successful applications of the approach in L1 writing instructions on primary school pupils (e.g., Sutherland & Topping, 1999; Wang *et al.*, 2006). L2 students, however, might be subjected to a "Language Threshold Hypothesis" which states that learners must have sufficient L2 knowledge in order to tap into their L1 writing skills (Williams, 2005). Their low proficiency in the target language often result in their greater attention in the lower-level form, i.e., transcription or production of written text including spelling (or the "shapes" of Chinese characters), vocabulary and grammar (e.g., Silva, 1993), than the higher-level content-related tasks, e.g., less planning (e.g., Yau, 1989) and reviewing (e.g., Silva, 1990). Language barrier poses a serious gap for L2 students to practice more advanced and cognitively demanding writing strategies, especially for younger children whose meta-cognitive skills are yet to be fully developed.

In this regard, Atkinson (2003) recommended the design of "post-process" approaches to L2 writing which are not intended to replace process pedagogy but rather to expand the domain of L2 writing. Likewise, Hinkel (2006) observed that many teachers and researchers advocated the integration of grammar and vocabulary with L2 writing instruction to enable writers to communicate meaningfully and appropriately. She noted how L2 writing pedagogy is putting more emphasis on the need to integrate bottom-up and top-down skills. This corresponds with the current trend for teaching integrated skills (Chetty, 2006).

Wiki for Collaborative Writing

The advantages of computer-based writing instruction have been investigated (e.g., Robinson-Staveley, 1990; Al-Jarf, 2002). These benefits include improved writing quality, increased teacher-student and student-student collaboration, as well as motivation to write and revise. Increasingly, writing teachers have incorporated Computer-mediated Communication (CMC) approach into their courses (Chao & Huang, 2007). One of the most popular CMC tools for writing instructions is the wiki, a web-based word/hypertext processor that supports multi-user asynchronous editing and version control, making it suitable for learners to practice collaborative writing and/or peer review. The wiki provides a solid ground on social interaction and collaboration (Godwin-Jones, 2003), which are the means to motivate the students to seek for outcomes beneficial to themselves and their peers instead of competing against each other (Johnson, Johnson & Holubec, 1994; De Pedro *et al.*, 2006). Moreover, Scardamalia & Bereiter (1994) speculated that one of the key drivers of collaborative writing is dissatisfaction in interplay; if students do not like the contributions taken by their peers, they may be more inclined to participate in order to make their own.

The user-friendliness and the open-endedness of the wiki have opened up the possibility for language learning researchers to design innovative collaborative writing and/or peer review approaches around the technology, e.g., scaffolding on wiki for collaborative writing (Chao & Huang, 2007), collaborative storytelling (Désilets & Paquet, 2005), collaborative writing on mobile devices (Sánchez-Villalon & Ortega, 2004), etc. Nevertheless, the use of Wiki in Chinese L1 or L2 writing instructions have been scarcely studied or reported to date – two examples were reported by Jiang & Xue (2006) and Ye & Zhou (2006); both were conducted in the L1 context in China.

Henceforth, we are keen on exploring new approaches to address Chinese L2 students' fundamental and pressing need in overcoming the "language threshold" before they proceed to learn advanced writing skills, while at the same time avoid the pitfalls of the traditional product writing pedagogy. Could collaborative writing be a plausible answer to our inquiry? Does wiki offer the affordances needed for such activities?

Study Description

The reported study involved three researchers from National Institute of Education and five Chinese Language teachers from two primary schools. The adopted professional development model of collaborative inquiry is a systematic approach to promote collaboration between researchers and practitioners to advance both knowledge and practice (Bray, 2002; Batliwala, 2003).

Our collaborative inquiry began with brainstorming to identify a "burning inquiry question" to tackle (i.e., pupils' writing), followed by figuring out typical challenges faced by the pupils in the context of the identified inquiry question (e.g., limited vocabulary, English-style grammar, etc.). We then proceeded to generate and design lesson ideas (i.e., V.S.P.O.W.) to address these challenges. Subsequently, one participating teacher piloted V.S.P.O.W. at her P4 class whose findings and experience will inform the inquiry group on future refinement of the design and more pilot studies to be conducted by other teachers. As this paper focuses on the lesson design and the pilot study, more details on the teachers' professional development aspect of the study will be reported in Wong, Gao, Chai & Chin *(forthcoming)*.

Lesson Design

The collaborative writing process of V.S.P.O.W. (see Figure 1) is intended to be a point-at-able model which offers the flexibility for the teachers to customize and execute for several rounds on the same group of pupils. The design is meant for pictorial compositions.

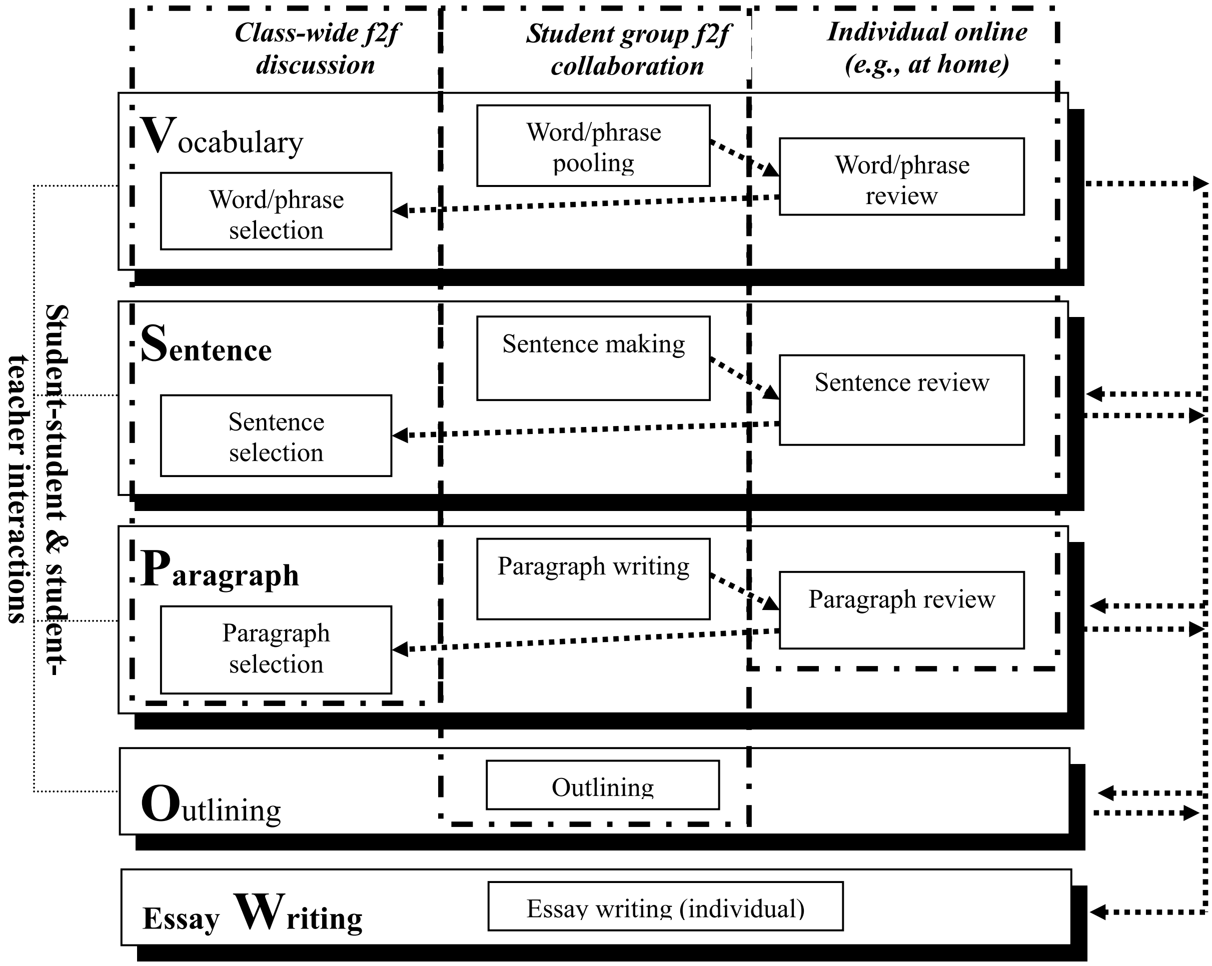

Figure 1. The V.S.P.O.W. process

The writing process consists of five major stages, namely, word/phrase pooling, sentence making, paragraph writing, outlining, and essay writing. Each of the first three wiki-based stages is subdivided into three similar steps, namely, intra-group collaborative "*pre-writing*" (i.e., word/phrase pooling, sentence making, or paragraph writing, depending on the stage), out-of-class intra- and inter-group online *reviews*, and class-wide *selections* – in other words, this is a blended learning approach . Wiki was selected as the platform to conduct the first three stages due to the tool's user-friendliness and strong support of asynchronous editing. In addition, Wiki's multi-page feature facilitates neat organization of various groups' work, and inter-group reviews and referencing.

We take the word/phrase pooling stage to illustrate on how the three steps are executed. The stage begins with pupils work in groups, face to face (f2f), to brainstorm Chinese words or phrases that describe the "content" (a scenario or a story) depicted by the given picture(s) – they take turn to input their personal contributions to their group wiki page. After that, the pupils log on to the wiki site from home to add on or edit their own groups' word lists. They could also browse through and learn from other groups' pages, correct mistakes, and place a question mark next to each of the words/phrases that they do not understand. The question marks signal the contributors of those words to add explanations on the respective pages. Finally, the teacher facilitates a class-wide discussion to review all the group word lists and select a recommended set of words/phrases. The recommended word list is then "fed" into the next stage as a reference for the pupils who proceed to make sentences in groups.

The same three-step process is repeated in the sentence making and paragraph writing stages, all making use of the same group wiki pages (see Figure 2 for a sample screen capture of a typical group wiki page for the first three stages of activities). The last two word processor-based stages are simplified as they both involve a single step each – collaborative outlining and individual essay writing.

Looking at the full picture of V.S.P.O.W., the first three stages could be considered as a process of "data" (word/phrase) collection and processing (sentence making and paragraph writing), which prepares the pupils to subsequently work on outlining and essay writing.

The entire process is highly customizable in the sense that pupils need not go through every single stage or sub-step – as indicated by the *dashed* arrows in Figure 1. Depending on the pupils' language ability, the teacher (or the pupils themselves) may choose to skip any combination of the stages or sub-steps. In other words, the approach allows for student differentiation. For example, high ability pupils may not bother to go through word/phrase pooling or sentence making before they proceed to write paragraphs.

On the other hand, as teachers may repeatedly execute rounds of V.S.P.O.W., they may opt not to execute complete cycles in early rounds for weaker pupils. For example, the process could be terminated at the sentence making stage in round 1, terminated at the paragraph writing stage in round 2; and complete cycles from round 3 onwards. Therefore, instead of being "intimidated" by the requirement of producing complete essays in early rounds, pupils could take their time to build up their low level writing skills. Based on the same principle, we envisage V.S.P.O.W. to be applied to pupils at lower primary levels, say, Primary 1 and 2 pupils to carry out "V.S.", and Primary 3 pupils for "V.S.P." or "S.P.".

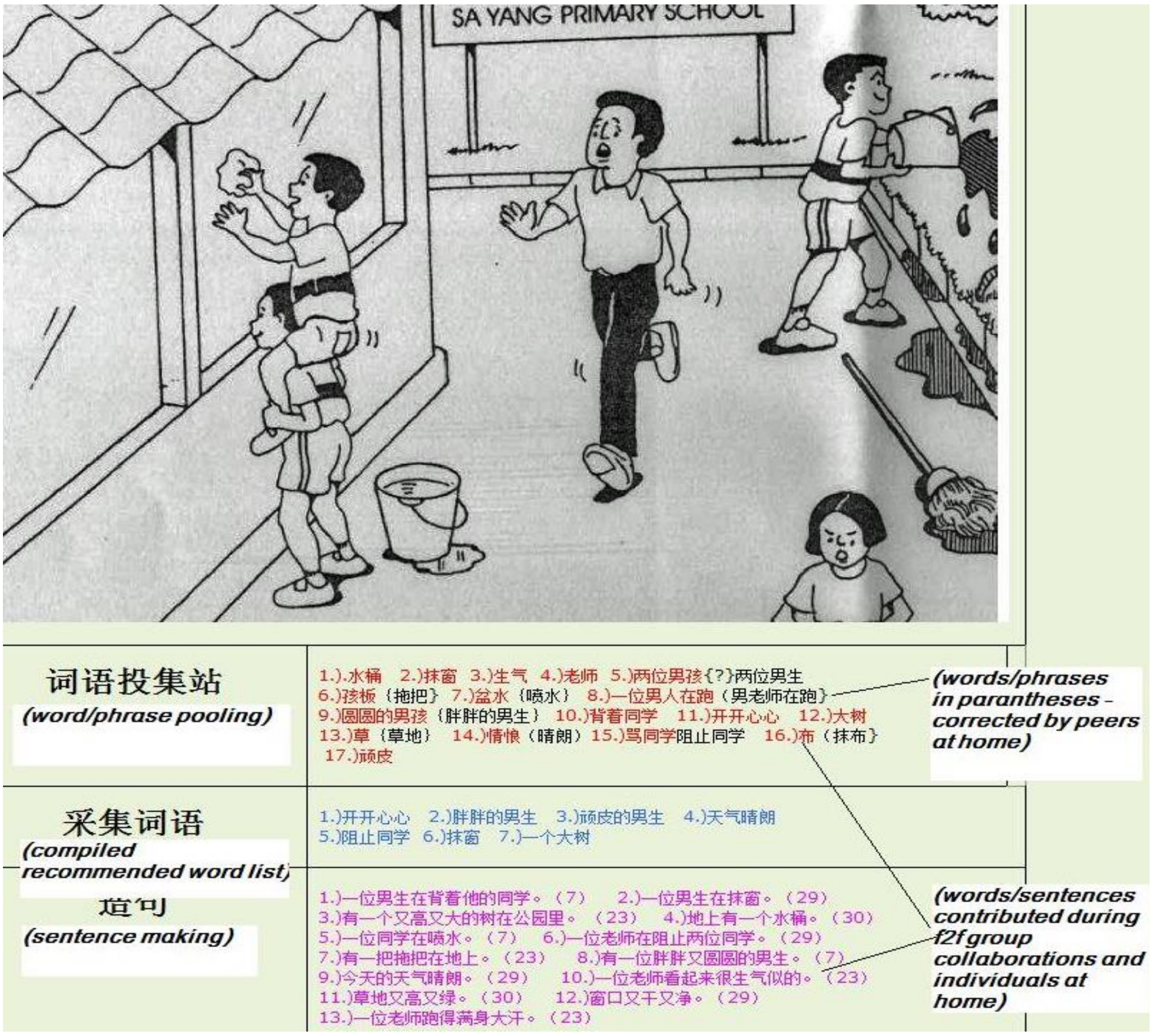

Figure 2. Screen capture of a group wiki page for the first three stages of V.S.P.O.W.

Pilot Study – Customization of the Writing Process

The pilot study took place in a class of 18 pupils. In the spirit of teacher empowerment, we advised the teacher to make her own decision on customizing V.S.P.O.W. and implementation details like pupil grouping; while we assumed the role of consultant in these matters.

Given the constraints in the resources and the academic schedule, the teacher executed 4 rounds of V.S.P.O.W. within 4 months. The pupils worked in the same grouping (4 groups altogether) as their regular ones in their mother tongue class, which were all heterogeneous (mixed abilities in Chinese proficiency) groups. No additional writing instruction beyond the pilot study was delivered to the class during the empirical period.

- Round 1: The teacher provided a picture that depicts spring cleaning in a school. The image is split into four zones, with each zone being assigned to one group for collaborative word/phrase pooling. All groups would then view the entire picture for sentence making. This round was terminated at the sentence making stage, i.e., the process was simplified as "V.S."
- Round 2: To make the writing activity more relevant to the them, the teacher arranged the pupils to take photos at the "Five-School Sports Games" (hosted by their school) held right before this round. The class discussed and selected one of the photos taken at a track competition. All groups skipped the word/phrase pooling stage but worked on the full photo in sentence making and then paragraph writing, i.e., the process was simplified as "S.P."
- Round 3: The teacher assigned each group a location in the school campus (e.g., the canteen, the garden, etc.), and instructed them to take a photo during recess time at the respective designated areas. Next, each group worked on the photo that they took for sentence making (they skipped word/phrase pooling). Subsequently, each group selected any three out of the four photos and collaboratively wrote a paragraph on each selected one. They then collaboratively prepared the outlines as reinforcement in essay structure. Eventually, they wrote their essays individually, presumably incorporating the outlines, the paragraphs and perhaps the sentences and words collaboratively generated by the class. Therefore, the process was simplified as "S.P.O.W.".
- Round 4: The teacher facilitated the entire class to brainstorm a story about a classmate getting caught cheating during a quiz. The class then acted out the story and took four photos. This time round, the teacher instructed the pupils to try out a hybrid collaborative "outlining-sentence making" approach on each photo, followed by collaborative paragraph writing and individual essay writing. In other words, the process could be represented as "O+S.P.W.".

Furthermore, the teacher provided different types of scaffolding in various rounds (e.g., 5W+1H), either on printed worksheets or the wiki. The time interval between two adjacent f2f sessions (e.g., between intra-group word/phrase pooling and class-wide selection of the word list, and so on) was typically one week, giving pupils some time to log on to wiki from home for individual reviews.

Pilot Study – Data Collection and Evaluation

To evaluate the impact of the pilot study we executed a data collection and analysis plan to measure the changes in the pupils' various micro-skills for Chinese writing and relevant perceptions/attitudes before and after the intervention. The plan consists of four components as described below.

First of all, we made use of two batches of pictorial compositions written by individual pupils during "ordinary" classroom sessions with paper and pen as the basis of the pre- and post-tests. The two batches of essays were written two weeks before the beginning and a week after the end of the pilot study respectively. The participating teacher and one of her colleagues were invited to mark the essays according to a rubric that we co-developed. The rubric consists of 9 items: punctuation marks, characters (correctness), vocabulary (richness), vocabulary (accuracy), sentence, organization, content ("observation capability" on the pictures), and content (analytical skills). Each item was graded by a scale of 1-5. The two teachers were required to mark the same 36 essays independently. As the rating scale is an interval scale, Pearson r coefficient was used to calculate the inter-rater reliability of the marking between the 2 teachers. The r values for all items range from .74 to .91, indicating good inter-rater reliability. Paired-sample *t* tests were then performed to examine whether there is improvement in pupils individual micro-skills in essay writing.

Second, we administered pre- and post-surveys to measure the pupils' perceptions and attitudes in learning Chinese, Chinese essay writing, and technology for learning and writing. All the pupils were asked to respond to questions on a Likert scale of four (1 = Strongly agree, 2 = Agree, 3 = Disagree, and 4 = Strong disagree). Paired-sample *t* tests were performed to examine whether there were changes in pupils' perceptions in those aspects. Additional questions were included in the post-survey to find out pupils' perceptions towards the V.S.P.O.W. activities; the results of which were examined by descriptive analysis.

Third, we invited three pupils of high-, medium- and low-ability in Chinese Language respectively from the class as selected by the teacher for one-to-one pre- and post-interviews. The intention was to find out more about the target students' perceptions and experience in their participations in the collaborative writing activities. Pseudonyms are used in this paper to protect the identities of the interviewees, namely, Haiqing (high-ability, female), Mingzhe (medium-ability, male), and Liguo (low-ability, male). They belonged to three different pupil groups in the writing activities.

Forth, our f2f, phone and e-mail interactions with the teacher throughout the course of the collaborative inquiry were also extracted as they often contain the teacher's first hand observation and reflection on the design and the pilot study which could serve as a means for triangulation of the first three set of data.

Findings

Improvement of pupils' micro-skills in Chinese writing (The cognitive domain)

Table 1 shows the results of the paired sample t-tests applied to compare the pupils' performances on the nine assessed micro-skills in the pre- and post-tests.

The results in Table 1 show that the pupils have achieved significant improvement in every assessed micro-skill for writing after the intervention. As the pre- and post-tests were paper-and-pen-based individual essays while the intervention was ICT-mediated collaborative writing, that probably implies a successful transfer of the micro-skills for writing that the pupils have improved through the intervention across the two different mediums and approaches of writing. In addition, the standard deviations (SD) of all items are dropped, indicating that the writing skill gaps among the pupils have also decreased.

A special micro-skill that has seldom or never been assessed directly in the context of essay writing is "content (observation)", or the ability of being "visually observant". When the teacher designed the collaborative activities for Round 1 where each pupil group was to focus on word/phrase pooling pertaining to a designated "zone" of the given picture, we predicted that the activities will help developing more visually observant pupils. This is not a linguistic but a cognitive skill to aid pupils in learning. Early evidence reported by the teacher was that the pilot pupils significantly out-performed their peers from other classes in describing the given picture in rich details during their school's mid-year Mandarin (spoken Chinese) oral examination which took place between Round 1 and 2 of the pilot study. Eventually, the pupils have also shown their vast improvement in the content richness of their pictorial compositions, as their scores improved by a mean difference of 2.00 out of the full score of 5 in this area ($t = 14.28$, $p < .001$).

On the other hand, we have also performed descriptive analysis on the pupils' self-reported areas of improvement via the post-questionnaire. According to our analysis, majority of the pupils agreed or strongly agreed that the four-round intervention has resulted in their "big" improvement in: the Chinese text input speed (88.9%), richness of the vocabulary used in their essays (83.3%), the sentence making skill (88.9%), the "excitement" of their essay content (88.9%), and the visual observation skill (100%).

Table 1: Paired-sample *t* tests between Pre-test and Post-test on Writing (N=18)

		Mean	SD	Mean Difference	*t*
Punctuation marks	Pre-test	3.6	.78	-.72	-4.58***
	Post-test	4.3	.49		
Characters	Pre-test	2.5	.79	-1.67	-11.90***
	Post-test	4.2	.51		
Words - richness	Pre-test	2.6	.70	-1.78	-13.76***
	Post-test	4.4	.50		
Words - accuracy	Pre-test	2.7	.75	-1.33	-8.25***
	Post-test	4.1	.54		
Sentences	Pre-test	2.7	.90	-1.44	-9.95***
	Post-test	4.2	.62		
Organization	Pre-test	2.9	.73	-1.22	-12.12***
	Post-test	4.2	.62		
Structure	Pre-test	2.8	.71	-1.50	-9.00***
	Post-test	4.3	.60		
Content - Observation	Pre-test	2.6	.62	-2.00	-14.28***
	Post-test	4.6	.51		
Content - Analysis	Pre-test	2.4	.60	-2.17	-17.87***
	Post-test	4.6	.51		

Note: *** $p < .001$

Pupils' perceptions (The affective domain)

We conducted paired-sample *t* test to examine if there were significance changes in pupils' perceptions toward Chinese language learning, Chinese compositions and ICT in learning and writing before and after the intervention (see Table 2). The results show significantly positive changes in the pupils' perception in the "beauty" of Chinese ($t = 4.93$, $p < .001$), writing Chinese compositions without looking at pictures ($t = 3.31$, $p < .01$) and the attitude toward the ease of using computer software ($t = 2.44$, $p < .05$). For the rest of the items, pupils held more positive attitudes as well although the changes were not significant.

On the other hand, we performed descriptive analysis on the pupils' responses to the post-questionnaire questions pertaining to their attitudes toward the intervention and yielded positive results. For example, 94.4% of the pupils agreed or strongly agreed that "I enjoyed the group composition activities"; 83.3% agreed or strongly agreed that "I wish I could participate in more rounds of the group composition activities"; 94.4% agreed or strongly agreed that the intervention "will help me in writing better compositions in the future."

However, perhaps due to the perceived unnaturalness of V.S.P.O.W., 61.1% of the pupils agreed or strongly agreed that "It is more difficult to write Chinese compositions with such a group composition activity than writing compositions all by myself", and 77.8% agreed or strongly agreed that "I still prefer writing Chinese compositions all by myself after participating in the group composition activities." We suspect that the pupils did not respond favorably to these questions due to their product-oriented attitude toward essay writing in general. They might have enjoyed and/or found benefits in the collaborative process but when it came to the "serious" work of producing essays, they preferred to revert back to their comfort zone – their "old" way of solo writing.

Table 2: Paired-sample *t* tests on pupils' attitudes (N=18)

		Mean	SD	Mean Difference	*t*
"I enjoy learning Chinese."	Pre-survey	1.6	.62	.11	1.00
	Post-survey	1.4	.51		
"Chinese is a beautiful language."	Pre-survey	3.0	1.09	2.40	4.93***
	Post-survey	1.6	.50		
"I have the confidence in learning Chinese well."	Pre-survey	1.8	.55	.22	1.29
	Post-survey	1.6	.71		
"I can write Chinese compositions without helping words."	Pre-survey	2.9	1.13	.33	1.10
	Post-survey	2.6	1.20		
"I can write Chinese compositions without looking at pictures."	Pre-survey	3.1	1.13	.94	3.31**
	Post-survey	2.2	1.04		
"I can write Chinese compositions without any help."	Pre-survey	2.8	1.11	.33	1.03
	Post-survey	2.4	1.10		
"I usually have no trouble in thinking about what to write in my Chinese composition."	Pre-survey	2.6	.98	.06	.14
	Post-survey	2.5	1.04		
"I think computer software is easy to use."	Pre-survey	3.4	.98	.78	2.44*
	Post-survey	2.6	1.15		
"I think I can learn more in class when the teacher uses technology."	Pre-survey	1.9	1.16	.33	1.03
	Post-survey	1.6	.70		
"If I can master Chinese computer input, I will be able to write better Chinese compositions."	Pre-survey	2.6	1.10	.50	1.34
	Post-survey	2.1	1.10		

Note: * p <.05, ** p < .01, *** p < .001

Pupils' collaborative (stage 1-4) & individual (stage 5) writing process

The post-questionnaire results show that the pupils were keen on helping each other during the collaborative writing activities. They unanimously (100%) agreed or strongly agreed that "I like to help my classmates during the group composition activities." 66.7% of them agreed or strongly agreed that "I prefer my classmates than my teacher to help me during the group composition activities."

The post-interviews have also revealed similar attitudes among the three interviewees. They all enjoyed helping others and being helped. Liguo, in particular, raised a case about a teammate whom he found "weird". During the pre-interview, he quipped that this teammate had "mental problem" apart from being weak in Chinese. When we asked him about this teammate during the post-interview, he said, "He improved a lot. I helped him in essay writing and oral, and brought him books. Now I don't have to help him anymore. I don't think he is weird anymore." Note that Liguo was a low-ability (in Chinese) interviewee as identified by the teacher prior to the study. Now his self-report reveals that he has not only taken the initiative to help a teammate whom he used to "despise", they seemed to become better friends in the process. We argue that Liguo gained pride and self-confidence through helping his peer, and that has helped him to improve his own writing skills as well.

How did the pupils work in groups help each other? How did the group dynamics work in terms of peer coaching? Due to the time constraint, we did not track the group writing process in the first pilot class of the project. Why could not we detect the f2f group interaction and peer coaching patterns through the investigation of the revision history on their wiki pages? This is because during the group-based f2f writing sessions, the pupils rarely saved their wiki pages; they typically did so after they had made a series of changes (sometimes, they saved their page only once – by the end of a session). Peer coaching was carried out verbally before "*helpees*" input their contributions or correct mistakes. There is no way the wiki technology could capture such interactions that are of our interest here. Nevertheless, we managed to gain some preliminary understanding in this aspect through the post-interviews and the post-questionnaire.

For example, we asked the interviewees the following questions, "Do you think you have helped your teammates more or the other way round?" "In what areas have you offered big helps to others and have others helped you?" Haiqing, who was perceived by her teacher as the best Chinese writer in her group, surprisingly told us that she was more a "*helpee*" than a helper, which contradicted with our commonsense that the "best" pupils usually dominate their learning groups. She claimed that she had helped her teammates in her strongest area – she was the fastest in Chinese computer input. She was weaker in sentence making and was grateful to her teammates' help (her teacher confirmed this and observed her vast improvement in this aspect after the intervention). Medium-ability Mingzhe believed he and his teammates had helped each other equally. They helped verifying each other's Chinese inputs (e.g, correcting wrong inputs). The greatest help that he has offered to the group was Chinese input while he gained helps mainly in vocabulary and sentence making. Finally, Liguo was not sure if he had helped his teammates more or the other way round. However, he proclaimed, perhaps both proudly and unpleasantly, "They (teammates) came up with the points (outlines). I then filled in with the complete story. They needed a little imagination but I needed a lot." Nevertheless, he was pleased to have learnt new vocabulary from his teammates.

We have also made use of the post-questionnaire to find out the areas that individual pupils perceived that they have offered or received the greatest helps in their groups. Although both questions allow multiple choices (from: *pinyin,* Chinese computer input, vocabulary, sentence making, paragraph writing, outlining, story, group leading), all the pupils only gave one answer to each question, which was an unexpected flaw in our data collection. We compiled two groups' responses to these questions in Table 3 as an illustration. Note that we have separated Chinese input and *pinyin*, the most commonly used phonetic-based Romanization scheme for Mandarin which is also the basis for the popular Chinese computer input method that the pupils had been using, as two distinguished items as there were indeed pupils who were good in *pinyin* (i.e., to figure out the correct *pinyin* of each Chinese character to input) but weaker in Chinese input (a kinaesthetic skill), or vice-versa. Haiqing, the high-ability interviewee, did indicate during the post-interview that she was a fast Chinese computer typist but often needed her teammates to correct her pinyin.

Table 3: How did pupils in Group A & E in the pilot study help each other?

Group A	Offered great help in	Helped a lot by teammates in	***Group E***	Offered great help in	Helped a lot by teammates in
Pupil A	words/phrases	outlines	Pupil E	pinyin	content/story
Pupil B	Chinese input	Chinese input	Pupil F	pinyin	pinyin
Pupil C	pinyin	pinyin	Pupil G	sentence making	pinyin
Pupil D	words/phrases	Chinese input	Pupil H	pinyin	pinyin
Mingzhe	pinyin	sentence making	Haiqing	Chinese input	sentence making

Although the data collected through these two questions are relatively coarse-grained, it does indicate that the pupils in each group has been coaching and complementing each other in different areas. For example, in Group E, Haiqing might have learnt a lot from Pupil G in sentence making. There were cases where a pupil perceived that she had offered and received great help in the same area (e.g., Pupil C, F and H in *pinyin*) – that probably indicates that she and most of her teammates were not so strong in this particular area but they managed to help each other or correct others' mistakes at different points of time. Such findings have inspired us to conduct a finer-grained qualitative study on the pupils' collaborative writing and peer coaching processes in our future rounds of pilot studies.

Discussion

The reported V.S.P.O.W. process was co-developed by us, the researchers, and a group of Chinese teachers with the pragmatic aim of addressing the fundamental linguistic challenges of juvenile pupils in Chinese as L2 writing. Objective-wise, it seems to be rooted in the current-traditional rhetoric pedagogy as described by Ferris & Hedgcock (1998). Yet it does not emphasize writing products as strongly, and neither advocates teacher's direct transfer of linguistic micro-skills and prescribed formulae in writing.

V.S.P.O.W. reinforces a collaborative writing process. Yet it seems to "violate" general principles of the "standard" process writing instructions. "Standard" process writing requires pupils to model after expert writers in writing. In other words, the "expert writing process" is both a *means* and the *end* to the pupils. However, L2 pupils typically struggle in linguistic-related micro-skills which hinder them from carrying out advanced process writing. V.S.P.O.W., on the other hand, is merely a *means* to help L2 pupils in improving their micro-skills mainly through emergent peer coaching, as revealed by post-interviews and the findings from the post-questionnaires presented in Table 3. There were prior studies on isolated activities to upgrade pupils' individual skills (e.g., see a survey in Graham, 2006, p.469-473). However, our design synergies the skills in a bottom-up writing process that is directly situated in the context of essay writing which should give the pupils a better sense of the relationships between individual skills and their writing.

Indeed, moving away from one-size-fits-all instructional design to adaptive, customazible learning design is the desirable direction of the 21st century education (e.g., Dede, 2005). A significant strength of the V.S.P.O.W. process is that it is highly customizable as demonstrated by the teacher in simplifying the process in various rounds of the pilot study, as well as varying other implementation details like the types of pictures for the pupils to work on. On the other hand, the pupil groups who participated in the pilot study did not exercise customization of the entire process by, for example, skipping intermediate steps, because the teacher did not advise them to do so. This was perhaps a justifiable move as the pupils were new to the writing process and they worked in heterogeneous groups with members at different levels of language proficiency.

However, according to our findings from the post-interviews, some pupils might have exercised another type of customization at the essay writing stage. The "data" that were collaboratively generated during the first four stages would become rich resources to aid the pupils in this final stage. There were studies on teachers providing similar resources for collaborative writing (e.g., Jiang & Xue, 2006); but in our design, such pupil-generated resources would extend a sense of ownership to the pupils. Nonetheless, each pupil could decide whether or not she would adopt the group-generated outlines, which group-generated paragraphs to adopt, to what extents she wants to make changes on the paragraphs, how to link the paragraphs together, or even re-write the entire essay from scratch. Some pupils may rely more on the group-generated paragraphs and make little changes on them; others may not bother to copy the paragraphs and instead leverage more on the group-generated sentences and/or words/phrases, and so on. Such flexibility may have further positive implication on the writing process in the context of individual differences which we are keen to investigate in the future.

Another significant characteristic of V.S.P.O.W. is the emergent peer coaching. Throughout the course of the empirical study, the pupils in each particular group who came with varied strengths in linguistic, writing, computer input and creative capabilities supported and complemented each other in carrying out respective tasks in various stages. Peer coaching had also taken place out of the f2f sessions where most of the pupils repeatedly logged on to the wiki pages from home to review and correct the contributions of their own and other groups. The aforementioned speculation of "dissatisfaction in interplay" by Scardamalia & Bereiter (1994) may explain this phenomenon.

The process and the outcomes of such spontaneous interactions also seem to echo Collins' (1997, p.3) argument that "learning difficulties reflect differences, not deficiencies." The pupils were more motivated to help each other when they worked in groups. They felt less threatened when they made mistakes, as their teammates (as compared to their teacher) who would "come into rescue" might have their own weaknesses after all. Consequently, they improved upon their weaker skills as well as gained pride and self-efficacy through helping others in what ones are good at. With such a social learning mechanism, it is hoped that peer coaching will be gradually faded out as all pupils will overcome their respective weaknesses (i.e., the reduction of differences and learning difficulties) and therefore could contribute to the collaborative writing process equally.

Conclusion & Future Work

Teaching juvenile L2 pupils in writing, which involve the most complex linguistic skills, has always been a great challenge to language teachers and researchers. The Chinese Language teachers in Singapore, for example, have been frustrated by their pupils' mediocre Chinese writing proficiency. In this project, we collaborated with a group of Chinese teachers to develop a wiki-based collaborative writing process to address such a challenge. The successful first pilot study implies that the approach (1) would result in improvement in pupils' micro-skills for writing and motivation in writing, mainly through emergent peer coaching; (2) is highly customizable by either the teacher or the pupils themselves to suit the linguistic proficiency levels of individual pupil groups; (3) turns the pupils' individual differences in the proficiency levels of various skills from a (perceived) instructional challenge to an advantage in motivating effective peer coaching. Such a design may fall under the emergent "post-process" paradigm for L2 writing as advocated by Atkinson (2003).

As we foresee a huge potential to scale up and sustain this approach in the schools, we intend to look into the following aspects in our subsequent rounds of researcher-teacher collaborative inquiry and pilot studies,

1. In our future pilot studies, we will make use of software for screen activity capturing to record the f2f

collaborations in selected groups. We will then code the video recordings and the changes made by the pupils on their wiki pages (as wiki supports automatic versioning) in order to analyze the interaction process and patterns in their collaborative writing and peer coaching in both f2f and asynchronous (logging on from home) modes;

2. Together with the teacher, we will explore the strategies to encourage pupil groups to negotiate meaning and/or bring in personal voices in interpreting the pictures;
3. We will study the relationship between the skills that the pupils have improved through the activities and the possible changes of their writing process or styles in their future "solo" paper-and-pen and computer-based writing;
4. We will identify another pilot class to go through V.S.P.O.W. which will be followed by "standard" process writing to find out if our approach does indeed prepare pupils to be better process writers;
5. We will experiment with the application of reduced versions of the process, e.g., V.S. and V.S.P., to lower primary school pupils.

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